LAKE TURKANA

A REPORT ON THE FINDINGS OF THE LAKE TURKANA PROJECT

1972 – 1975

VOLUME 5

EDITED BY A. J. HOPSON

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A REPORT ON THE FINDINGS OF THE LAKE TURKANA PROJECT

1972-1975

GOVERNMENT OF KENYA AND
THE MINISTRY OF OVERSEAS DEVELOPMENT, LONDON.

EDITED BY A.J. HOPSON

Volume 5 of 6 Volumes

OVERSEAS DEVELOPMENT ADMINISTRATION
LONDON
1982

Published 1982 Institute of Aquaculture
University of Stirling
STIRLING FK9 4LA
Scotland

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ISBN 0 - 901636 - 41 - X

Produced, Printed and Bound at the University of Stirling

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CHAPTER 11

THE BIOLOGY OF PERCIFORM FISHES

by
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THE BIOLOGY OF *Lates niloticus* (L) IN LAKE TURKANA

A J Hopson

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INTRODUCTION

WORTHINGTON (1932) described two subspecies of *Lates niloticus* from Lake Turkana, *L. n. rudolfianus*, a large perch occurring widely throughout the lake, and *L. n. longispinis*, a smaller offshore form. They are now considered to be separate species (GREENWOOD, 1976). The larger has proved to be indistinguishable from *L. niloticus*, a form which occurs throughout the soudanian region of Africa, and the smaller, *L. longispinis*, is endemic to Lake Turkana. The present account deals with the biology of *Lates niloticus*, the Nile Perch. This species is of considerable commercial importance in the Turkana gillnet fisheries and formed 27% of the total catch during 1974. The Nile Perch is also a valuable sporting fish and angling is one of the chief attractions for visitors to the three safari lodges situated on the shores of the lake.

HOPSON (1972) reviewed the existing literature on *L. niloticus* in an account of the natural history of the Lake Chad population. A valuable synopsis of the biology of the species in East African lakes (GEE, 1969) appeared shortly before the Lake Chad study went to press but was omitted from the bibliography. More recently two important works have been published. LOUBENS (1974) provides a comparison between the biology of populations of L. niloticus occurring in the southern basin of Lake Chad and in the River Chari, the principal inflow. COULTER (1976) describes the biology of four species of Lates (Luciolates) occurring in Lake Tanganyika and discusses their status in pelagic fisheries.

In Lake Turkana, pioneer investigations on the biology of L. niloticus were made by WORTHINGTON and RICARDO (1936) who analysed data collected chiefly in the vicinity of Longech during the 1930-31 Cambridge University expedition. Notes on condition factor, length at maturity, sex ratio and breeding are provided, based on a sample of 54 fish ranging from 11 to 190 cm TL.

Subsequent observations were made during the course of brief visits to Lake Turkana by workers from the East African Freshwater Fisheries Research Organisation, Jinja, during the period 1960-65. HAMBLYN (1960) comments on reproductive state and feeding, while GEE (1966) discusses condition factor and the distribution of juveniles in the Ferguson's Gulf area.

The present study is based on a total of ca 2100 fish examined during the period June 1972 - October 1975. They ranged from 6 cm to 190 cm in total length but the majority were mature or maturing fish of over 60 cm TL. Post-larval and small juvenile Lates were caught in considerable numbers during the investigations, but it proved impossible to distinguish between the early stages of L. niloticus and those of L. longispinis. Data on these small fish are analysed in a separate section below (see page 1301).

Aspects of the biology of L. niloticus studied during the present investigations included distribution, growth, reproduction and food. Preliminary studies proved that in the absence of seasonal checks on scales and opercular bones, age determination was not possible, and the number of fish in monthly samples was too small for Petersen's method of length frequency analysis to be employed.

MATERIAL AND METHODS

Routine bottom trawl catches from all areas of the lake provided approximately 1200 of the 2100 fish investigated during the present study. Further information was derived from ca 300 fish caught in the frame trawl and in gillnets set both on the bottom and on the surface.

The examination of Lates niloticus was carried out on board R V HALCYON immediately after capture. Total length was measured to the nearest 1 cm below and the weight recorded to within an accuracy of 1%. Data on gonadial state, food and in many cses ectoparatites, were also obtained.

Detailed records of fish caught by anglers at the Longech Angling Lodge, compiled by the manager, Mr Sandy Robertson, provided a valuable source of supplementary information. The observations, which include length and weight measurements, sex, gonadial data and notes on food, cover the period February 1973 to July 1974 and relate to a total of 594 fish.

A comparison of length frequencies of bottom trawl and angling catches (Fig. 11.1) shows that although the trawl caught a much higher proportion of smaller size groups, the size structure of catches of fish over 90 cm TL was similar in the two samples. The results strongly suggest that the true size structure of the population of larger fish is represented by the histograms and it is probable that the trawl provided random samples of all L. niloticus above the mean retention length.

DISTRIBUTION

Lates niloticus proved to be a widely distributed species in Lake Turkana, occurring both offshore and inshore. The species was caught in various types of fishing gear including bottom, midwater and frame trawls, gillnets, shore seine and by rod and line.

The most detailed information on the distribution of L. niloticus was obtained by bottom trawling and records, grouped on a seasonal basis, are summarised by charts in Fig. 8.16 a-c (see Chapter 8). The distribution charts indicate that in openwater situations L. niloticus was most plentiful in the Northern Sector of the lake where a large proportion of hauls included the species and catch per effort was high. Away from the Northern Sector offshore catches were relatively low, often including only a single large individual and the fish became scarce in the open waters of the southern basin. Similar trends were observed in the distribution of potential prey species including Hydrocynus forskalii and Lates longispinis.

Lates niloticus was at times abundant in inshore catches both in the Central and Southern Sectors of the lake, particularly in Allia Bay on the east shore where vlues of catch per effort as high as 700 kg/hr were recorded (Fig. 8.16). No marked seasonal trends are suggested by the distribution charts.

The relative importance of Lates niloticus in bottom trawl catches is illustrated in Figure 8.4 (see Chapter 8). In the Central and Southern Sectors the species dominated inshore catches but showed a marked decline in importance offshore. The situation was reversed in the Northern Sector where the proportion of L. niloticus tended to increase with depth.

Figure 11.2 illustrates how the depth distribution of Lates niloticus varied with size. Mean catch per effort for bottom trawl catches has been calculated in both No/hr and kg/hr for each 10 cm length class in each 10 metre depth zone. It is evident that the smallest fish were restricted to the shallowest water and that with increasing size L. niloticus tended to extend gradually offshore. Up to a length of 80 cm the fish were still almost entirely confined to depths of less than 30 metres and catch per effort was highest close inshore. Larger fish penetrated into deeper water beyond the 30 metre contour and from a length of 100 cm upwards, values of catch per effort showed little tendency to change with depth, indicating that the larger fish were more randomly distributed over the lake. It is significant, however, that although L. niloticus were regularly caught in the 50-60 cm depth zone, none was recorded in 20 trawl hauls made at depths between 70 and 110 m. It would appear that the species was completely absent from the deepest layers of the lake.

The high proportion of everted stomachs in trawl hauls from deeper water (see page 1294) indicates that most fish were caught on or near the bottom. Data from the midwater trawl survey show that *L. niloticus* also occurred as a pelagic species in the midwater layers. Three individuals ranging from 80-129 cm were caught during a total of 80 midwater hauls. In each case the net had sampled the top 10 metres of the water column (Table 8.13). Further examples of large *L. niloticus* occurring pelagically in the open waters were recorded in the frame trawl (Fig. 8.31), in surface gillnets set in mid lake (Table 8.25m) and in midwater gillnets (Table 8.23). These results indicate that the species occurred regularly in the midwater layers. Concentrations were probably highest in areas where the midwater scattering layer was dense and potential prey species, such as *Schilbe uranoscopus* and *Lates longispinis* were common.

It was more difficult to quantify populations of *L. niloticus* in inshore areas of the lake. The shallow water regions of the trawl survey were sampled with surface set gillnets of 6-9 mm mesh. Results from various localities on the east shore are shown in Table 8.26. *Lates niloticus* was in most cases a common species and usually dominated the catches.

Samples were obtained with a 50 m beach seine of 19 mm mesh from a wide range of localities in all sectors of the lake but numbers of *L. niloticus* were always low. Data combined from all stations (Fig. 11.3) show that approximately half the catch consisted of fish ranging from 5 to 30 cm TL, a group which was not represented in the trawl catches from slightly deeper water offshore. HAMBLYN (1962) noted that in Lake Mobutu (formerly Lake Albert) juvenile *L. niloticus* of below *ca* 20-30 cm were restricted to marginal areas in the vicinity of submerged vegetation, and HOPSON (1972) noted a similar pattern of distribution in Lake Chad. It seems likely that in Lake Turkana the juveniles principally inhabited beds of submerged *Potamogeton* which occurs chiefly on the east shore of the lake. Dense vegetation was avoided during seine netting and it is probably for this reason that the recorded numbers of juveniles was low.

The shore seine data (Fig. 11.3) indicate that larger fish of all sizes penetrated close inshore. This observation is supported by evidence from angling. *Lates niloticus* of up to a size approaching the maximum were regularly caught by angling from the shore, particularly in rocky areas where the water shelved deeply. It is impossible to assess population densities in such situations but *L. niloticus* appears to occur commonly on rocky shores throughout the lake, including the precipitous coastline of the southern basin where it preys on the rich populations of *Tilapia zillii* and *Sarotherodon niloticus*.

COMMERCIAL CATCHES

The distribution of *Lates niloticus* in eight co-operative areas situated on the west shore of Lake Turkana (see Chapter 6) is illustrated in Table 11.1 where data for two consecutive twelve month periods are compared. Marked regional differences are apparent. Highest landings were recorded in the Todenyang and Kerio areas where fishing effort was also highest and where wide expanses of relatively shallow water provided a particularly favourable habitat for the species. There is no significance in the fact that the two stations were situated in the vicinity of the major river mouths. Lates niloticus is non-anadromous and a tendency for fish to concentrate near river mouths during flood periods was not observed.

In most areas catches varied only slightly during the two periods and the increase of total catch from 348 tonnes in 1972/73 to 470 tonnes in 1973/74 resulted from a considerable rise in yield at Kalakol. The rise was due to the expansion of the fishery into new grounds on the east side of the lake between Allia Bay and Moite.

Lates niloticus was chiefly caught in gillnets, although since 1973 a small proportion of the catch has been taken on long lines, particularly in the Nachakui-Namudak region. A decrease in mesh size in recent years (see Chapter 6) has led to a fall in the modal length of L. niloticus in the commercial catch from about 80-90 cm to 55-70 cm TL. Immature fish are increasingly caught.

Lates are normally split open, salted and sun dried. The flesh of larger individuals over ca 130 cm is cut into slender strips and salted in the same way.

GROWTH

AGEING AND GROWTH RATES

Previous studies of Lates niloticus in Lake Chad (HOPSON, 1972; LOUBENS, 1974) have shown that an annual fall in lake temperature of approximately 10° C during the winter months resulted in the formation of an annual growth check on the scales which was satisfactorily used as a key to age determination.

In Lake Turkana, water temperatures are stable with an annual range of only ca 2° C. Although growth checks were evident on the scales of Lates niloticus, they proved to be laid down regularly and were clearly not influenced by a seasonal cycle of environmental change. Under such circumstances scales provided no clue to ageing. The identification of age cohorts by Petersen's method of length frequency analysis was impossible with the Lake Turkana data due to the small size of the monthly samples and the unusually large length and age range of L. niloticus. Tagging proved to be too time-consuming for large scale application, and furthermore, most of the reliable sources of L. niloticus were located in remote areas distant from commercial fishing grounds where there was only a small likelihood of recapture.

In the absence of direct observations on ageing and growth, a tentative estimate has been based on the assumption that observed differences in the length at maturity between Lake Turkana and Lake Chad populations indicate comparable differences in growth. A comparison of data from the two lakes (see page 1292) shows that although a marked sexual difference in length at maturity was observed, the length of Lake Turkana fish was approximately 35% greater in both males and females. For the purpose of the present exercise it is thus postulated that the proportional difference in length for age between Lates niloticus from the two lakes remained unchanged at 35% throughout life.

HOPSON (1972) found that in Lake Chad, there was no sexual difference in the growth of L. niloticus and that for the first five years of life the form of growth was well represented by a von Bertalanffy model with the parameters L_∞ = 93.1 cm, K = 0.272 and t_0 = 0.046 years. Subsequently, in fish aged 6 years and above, growth changed to an arithmetic pattern represented by the equation

$$L = 31.96 + 7.681\ t$$

where L = length in cm and t = age in years. COULTER (1976) noted a similar divergence from a fitted von Bertalanffy curve in larger Lates mariae from Lake Tanganyika.

Estimates of length for age (Table 11.2) in the Lake Turkana population were obtained by applying a factor of 1.35 to lengths derived from the two expressions quoted above for Lake Chad fish. Weights were calculated by using the length/weight expressions discussed below.

LENGTH WEIGHT RELATIONSHIP

The relationship between length (l) and weight (w) in fish is usually represented by:

$$w = a\ l^b$$

Length-weight data for a total of 173 females ranging from 35 to 184 cm and 250 males of 31 to 144 cm TL were recorded during the present investigations. Values of a and b were obtained by using the logarithmic form of the above equation and fitting linear regressions. The following values for a and b (with w in gm and l in cm) were obtained:

	a	b	r^2
Females	0.0070	3.124	0.95
Males	0.0061	3.162	0.99
Both sexes combined	0.0071	3.125	0.97

CONDITION FACTOR

Values of condition factor K were calculated from length-weight data for all male and female L. niloticus using the formula:

$$K = \frac{100w}{l^3}$$

where w is the weight in gms and l is the length in cm. Mean values of K have been worked out separately for each sex, for all 10 cm length classes (Table 11.3). There was a marked tendency for $\bar{K}$ to increase with size in both sexes, indicating that the relative weight became higher in longer fish. Thus $\bar{K}$ ranged from 1.05 in the smallestsize group to 1.51 in the largest (Table 11.3). The trend probably resulted from both an increase in relative weight, due to the maturation of gonads during sexual maturity, and from allometric growth. It is noticeable from Table 11.3 that sexual differences in $\bar{K}$ were slight over most of the size range with the exception of 70-90 cm fish where values for males were appreciably higher. This discrepancy is explained by gonadial evidence (see below) which shows that males of 70-90 cm had already undergone sexual development whereas females were not fully mature.

Changes in condition factor with size have been noted in other species of *Lates*. During the present investigtions it was found that in the dwarf perch *L. longispinis* $\overline{K}$ tended to decrease from a value of about 1.27 in fish below 5 cm TL to 0.92 in individuals of 45-50 cm approaching maximum length. These changes were caused by a tendency for the relative length of the caudal peduncle to increase with size. COULTER (1976) working on *Lates* populations in Lake Tanganyika found that in both *L angustifrons* and *L.microlepis* K rose steadily with size to reach a peak in fish of 50-60 cm. In *L. mariae* values tended to remain relatively constant in adults.

BREEDING

GONADIAL STAGES

Gonadial stages of *L. niloticus* have been described in detail for the Lake Chad population by HOPSON (op. cit.). Briefly they are as follows:

Females

Stage 2	Virgin/Resting
Stage 3	Early maturing
Stage 4	Late maturing
Stage 5	Ripe
Stage 6	Running
Stage 7	Spent

Males

Stage 2	Early
Stage 3	Early developing
Stage 4	Mature resting
Stage 5	Ripe
Stage 6	Running
Stage 7	Spent

The ovaries revert to Stage 2 after spawning and undergo a subsequent cycle of oogenesis and maturation before further spawning is possible. Spent males usually revert to Stage 4 but in Lake Turkana a small proportion of fish over 100 cm TL had narrow Stage 3 testes with no trace of milt in the lumen. It seems probable that these fish were post spawners in a resting stage.

SIZE AT MATURITY

Data relating to maturity in males and females are presented in Tables 11.4-5. The results indicate that the length at first maturity in individual males varies considerably. Thus although a Stage 4 male was noted in the 45-49 cm class, a clear majority of Stage 4 and 5 fish was not recorded until 65-70 cm TL. The percentage of Stage 4-6 fish continued to rise up to a length of 75-80 cm (Table 11.4) after which it remained relatively constant, suggesting that all individuals had matured. The smallest ripe male was a fish of 65 cm TL. Data in Table 11.4 indicate that the length of 50% maturity in the population of males was reached at approximately 65 cm TL.

In females (Table 11.5) no sign of maturation was observed in fish below 65 cm TL and the smallest ripe (Stage 5) female measured 83 cm TL. Interpretation of the results for females is confused by the fact that in the post-spawning fish the ovaries revert to Stage 2 and are not always easily distinguishable from the gonads of virgin females. However, the proportions of the various maturity stages in Stage 5 became comparatively steady at lengths about 90 cm, indicating that most females had matured at this length.

The present results are in agreement with WORTHINGTON and RICARDO (1936) who noted that in Lake Turkana male and female L. niloticus were immature at lengths below 60 and 80 cm respectively. The Lake Turkana population matures at a considerbly larger size than was observed in the northern basin of Lake Chad where HOPSON (1972) recorded lengths at 50% maturity of 50 cm for males and ca 62.5 cm for females. Breeding in certain riverine populations occurs at an even smaller size. LOUBENS (1974) noted ripe females of 34 cm TL in the basin of the River Chari, and HOPSON (op. cit.) reported a Stage 4 female of only 27 cm TL in the Volta Basin. It seems likely that the observed differences in length at maturity are correlated with differences in growth rate.

SEASONAL CHANGES IN MATURITY

Data relating to maturity stages for the period June 1972 to October 1974 have been combined on a monthly basis for the larger males and females in Tables 11.6 and 11.7 respectively. The results suggest that spawning in L. niloticus persisted for most of the year with a slight rise in activity during the flood season, indicated by the higher proportion of ripe and ripening females between June and September (Table 11.7). The comparatively low percentage of Stage 4-6 females in October and November may mark a temporary check in breeding activity following the peak. Results for males show a different seasonal pattern and the percentage of ripe individuals was relatively low between February and June, falling to a minimum of 12% in April.

The evidence provided by post-larval and juvenile Lates (see page 1301) is consistent with prolonged spawning. Post-larval Lates of 6-10 mm were observed in metre townet catches in all areas of the lake, throughout the year, and juveniles of 15-30 mm were always present on the lake margin. Since breeding in L. longispinis was confined principally to the months of January to March it is probable that for much of the year the early stages of L. niloticus alone were involved. Continuous year-round spawning in L. niloticus populations in Lake Turkana is probably correlated with the exceptionally stable lake temperatures. In Lake Chad where a fall of up to 13°C occurred during the winter months, HOPSON (1972) reported that in L. niloticus breeding extended over an annual period of nine months commencing with an initial peak in March and April. Activity ceased completely between December and February, the coldest period of the year.

SPAWNING GROUNDS

HOPSON (1969, 1972) located the spawning areas of L. niloticus in Lake Chad by plotting the distribution of pelagic eggs and early larval stages. It was found that the eggs were chiefly concentrated in sheltered channels in the dune island system on the east side of the lake. Spawning probably occurred at a lake depth of 2-3 metres, but no direct observations were made. The mean length of larvae tended to increase with distance from the spawning area.

During the present studies, concentrations of Lates eggs were never found, although numerous hauls were made with a coarse plankton net in marginal areas of the lake. Solitary eggs were occasionally observed in routine zooplankton samples collected with the 5" Clark-Bumpus net (see Chapter 3). However, post-larvae ranging from 5 mm and upwards were regularly caught in metre townet hauls and their ubiquitous distribution (Figs. 8.58) indicates that the spawning sites of one or both species of Lates were scattered throughout the lake. Since spawning was confined to a limited season in L. longispinis, it may be assumed that for much of the year the post-larval population was dominated by L. niloticus and that this species, at least, bred widely.

Although the observation quoted above from Lake Chad suggests that spawning grounds might be situated in marginal areas of Lake Turkana, the only direct evidence was obtained during the present studies from a deeper offshore area. Figure 11.4 shows an echo trace recorded in the course of a bottom trawl haul in mid-lake 23 km north of North Island at a lake depth of 26 m during September 1974. The trace represents an unusual concentration of fish rising in a loose shoal above the bottom. The trawl, which has passed through the base of the shoal, caught unusually large numbers of L. niloticus consisting of 21 ripe-running males of 73-101 cm TL and one ripe-running female of 130 cm. It seems probable that the shoal was a breeding concentration of Lates niloticus, indicating that spawning may take place in the open lake well away from the shore. The ripe-running female was one of only three observed during the entire survey, the other two being recorded in the vicinity of Longech Spit.

SEX RATIO

Sex ratio (defined as the number of females per 100 males) was found to vary in Lates niloticus both with size and with locality (Table 11.8). In trawl catches, males outnumbered females in all length groups between 30 and 100 cm, and in three cases the sex ratio was significantly lower than 100. At lengths of over 110 cm females became increasingly predominant in the trawl catches, and between 130 and 150 cm males were outnumbered by about 20:1. A male of 145 cm was the largest observed during the present investigations but females reached a maximum size of 185 cm (Table 11.8). Results from the Longech Angling Lodge differed considerably, and in nearly every length class females outnumbered males, with a significantly higher proportion in all groups over a length of 80 cm.

Almost all angling catches were made close inshore in the approaches to Ferguson's Gulf at depths of 4-10 metres. A proportion of the trawl hauls were also made within the 10 metre contour but sampling stations never approached the lake margin so closely. It is therefore probable that the difference in sex ratio between the two

two series of observations was due to a tendency for the distribution of females to be more concentrated in inshore areas of the lake. HOPSON (1972) observed similar trends in female L. niloticus in Lake Chad.

The dearth of males in larger size groups and their low maximum size in relation to the largest females are features which appear to be common to most populations of L. niloticus. Comparable results have been obtained in Lake Mobutu (formerly Lake Albert) (WORTHING, 1929), the Blue Nile at Sennar (KENCHINGTON, 1939) and in Lake Chad (HOPSON, 1972). Pronounced sexual differences in mortality are the probable cause.

FOOD

Stomachs of Lates niloticus were examined during the routine collection of catch data on board R V HALCYON. The recording of food items was based on a volumetric method described by HYNES (1950). Stomach fullness was estimated on a 16-point scale ranging from 0/16 (empty) to 16/16 (full). The number of points scored by the total volume of food present was divided between the various food categories. Details of prey size were recorded whenever practicable. A separate tally was kept of fish with everted stomachs which were common in trawl catches from deeper water. This phenomenon was the result of rapid decompression which caused the gas bladder to expand, forcing the stomach up through the oesophagus into the mouth.

Records of food were obtained for a total of 1100 fish, ranging from 30 to 175 cm in length, and caught chiefly in the bottom trawl. These data have been analysed on the basis of length in Table 11.9. The number of points scored by each food category is expressed as a percentage of the total points recorded for a particular length class. Percentage fullness was obtained by expressing the total observed score as a percentage of the maximum possible score from fish with stomachs in situ. Fish with everted stomachs were discounted when the percentage of empty stomachs was calculated.

The results (Table 11.9) demonstrate that L. niloticus of the size range under consideration were almost entirely piscivorous in Lake Turkana with invertebrate food, chiefly Anisoptera nymphs, occurring in only the smallest length classes. Prawns were rarely eaten and formed more than 1% of the food intake only in 40-49 cm fish.

Cichlids, chiefly Sarotherodon niloticus, were the dominant prey category at all sizes. The larger cichlids are almost entirely confined to areas of the lake within the 10 metre contour and the preponderance of this group in the diet reflects a sampling bias in favour of inshore locations. It was observed that at certain shallow water trawl stations, particularly in Allia Bay, cichlids formed almost the entire food intake. Under such circumstances the stomachs often contained fragments of Potamogeton in addition to the fish. This suggests that predation had occurred in the vicinity of submerged beds of vegetation lying shoreward of the trawling grounds. Sarotherodon and Tilapia were not observed in the food of L. niloticus at depths greater than 10 metres.

Changes in the food preference of *L. niloticus* with increasing size are evident in the results. Thus *B. bayad* was unrecorded in the smallest perch but the proportion increased steadily from a length of 50 cm and upwards to reach a peak of 30% in the 110-120 cm length class (Table 11.9). This trend was probably due to the comparative rarity of *B. bayad* in inshore areas to which the smaller *L. niloticus* were restricted (Fig. 11.2). Smaller food species tended to be preyed on most intensely by *L. niloticus* of intermediate size, from 50 to 69 cm in the case of *Chrysichthys auratus* and from 80 to 90 cm in the case of *Lates longispinis*.

The present data support evidence from trawl surveys which indicate that *L. niloticus* ranges widely through the water column in deeper water offshore. The food included not only the dominant demersal species *Bagrus bayad*, but pelagic forms such as *Hydrocynus forskalii*, *Alestes ferox*, *Schilbe uranoscopus* and *Lates longispinis*, indicating that food was regularly sought in the midwater layers.

The low incidence of *Synodontis schall* in the diet of all size groups was unexpected, since survey data (see Chapter 8, Table 8.5) had indicated that this was the most abundant species of medium-sized fish in the open waters of the lake. The evidence suggests that *L. niloticus* tended to avoid *S. schall*, almost certainly on account of the strong, locking, pectoral and dorsal spines. The fatal effects of these were illustrated during the present survey when a perch of *ca* 140 cm TL was found floating in a weak condition on the surface with a live 25 cm *S. schall* wedged inextricably in its throat, held tightly in position by the spines. A small proportion of larger *L. niloticus* were observed to have detached *Synodontis* spines embedded in the stomach wall.

The percentage of empty stomachs in the various length classes varied from 27 to 59% (Table 11.9) but showed no tendency to change progressively with size. Relative fullness also fluctuated independently of size between extremes of 15 to 26%. Everted stomachs, however, became increasingly more frequent with size from an incidence of zero in the smallest fish increasing to 34% in the largest. This trend is correlated with the distribution of *L. niloticus* where, as shown previously, the smallest fish were confined to the inshore region of the lake and only gradually moved offshore with increasing size to depths where stomach eversion was likely to occur.

The relationship between size of *Lates niloticus* and that of the principal prey species recovered from the stomachs is illustrated in Figure 11.5. In four species, *Hydrocynus forskalii*, *Bagrus bayad*, *Clarias lazera* and *Sarotherodon niloticus* a maximum prey length of approximately 50% the length of the predator was observed. These were exceptional and in elongated fish such as *H. forskalii* and *Bagrus bayad*, prey of up to only one third the length of the predator was regularly eaten.

The evidence suggests that the presence of an elongated dorsal spine in *Lates longispinis* resulted in a substantial fall in the relative length at which the species was commonly eaten. Although in one instance a relative prey length of 38% was observed, *L. longispinis* exceeding 25% were rare in the food of *L. niloticus*.

The strong, locking, dorsal and pectoral spines of *Synodontis schall* and *Chrysichthys auratus* were clearly important in reducing predation. These fish were rarely taken at lengths of over 22% that of the predator although in one instance a relative length of 28% was recorded in *S. schall* (Fig. 11.5).

A comparison of the present results with observations on the feeding of *Lates niloticus* in Lake Chad (HOPSON, 1972) shows considerable difference in diet. Prawns were a dominant item in the diet of the Lake Chad population, particularly in offshore areas of the lake where they formed over half the intake of food in fish up to 55 cm TL. Small characins of under 4 cm FL were also an important source of food in fish up to 80 cm. Prawns and small characins occurred commonly in the open waters of Lake Turkana but food resources were clearly partitioned between the two species of *Lates*. The present investigations proved that *L. longispinis* was the species which exploited prawns and the small pelagic characin *Alestes minutus* (see page 1322). Smaller *L. niloticus* corresponding in length to *Lates longispinis* were restricted to the inshore areas of Lake Turkana where they fed chiefly on cichlids. The larger fish, which extended offshore and overlapped in distribution with *L. longispinis*, exploited completely separate food resources formed by larger species of open-water fish.

Observations on the relative size of prey in the Lake Turkana population of *L. niloticus* agree closely with results from Lake Chad (HOPSON, *op. cit.*) where the maximum prey length also approached 50% of the length of the predator.

A study of feeding of post-larval and early juvenile *Lates* spp. is presented in Chapter 12.

ECTOPARASITES

Three species of copepod parasite were identified from *Lates niloticus* in Lake Turkana during the present investigations. They consisted of two argulids, *Argulus cunningtoni* Fryer and *Argulus rhipidiophorus* Monod, and a lernaeid, *Opistholernaea longa* (Harding). No distinction ws made between the two species of *Argulus* in the field.

An anaylsis of field data (Table 11.10) proves that *O. longa* was principally offshore in distribution, whereas the argulids were confined to inshore areas. The mean number of lernaeids per fish rose from 1.6 per fish in the shallower depth zone to 27.4 per fish at depths below 20 m, where as many as 95 individuals were recorded on a single *L. niloticus*.

Opistholernaea longa was firmly anchored to the host, chiefly on the ventral surface, and where parasites had become detached, an obvious lesion remained. Fish from the 0-10 m depth zone, where a maximum of five *O. longa* per fish was observed, never showed signs of multiple lesions. The evidence suggests that *L. niloticus* tended to move relatively little from deeper water, and it seems probable that the larger fish were somewhat sedentary in their habits. *Lates longispinis* which was confined to offshore waters of the lake was also frequently heavily infested with *O. longa*, but argulid ectoparasites were never observed (see page 1325).

SUMMARY

Lates niloticus is the larger of the two *Lates* inhabiting Lake Turkana. Juvenile fish of under ca 30-40 cm TL are confined to the inshore regions of the lake, particularly in well-vegetated sites but with increasing size, the distribution extends further offshore. Thus fish of over 100 cm TL are relatively evenly distributed both inshore and offshore as far as the 60 m contour. The species ranges widely within the water column and occurs both in bottom trawl catches and in samples from the midwater and surface layers.

No direct evidence for establishing age or growth rates was obtained but it was noted that the length at sexual maturity was ca 35% higher in Lake Turkana than in the Lake Chad population of *L. niloticus* for which growth parameters have been estimated. It was postulated that the growth rate of the Lake Turkana population is also 35% higher.

Mean condition factor tends to increase with size. This is attributed to the onset of sexual maturity and to allometric growth.

Female *L. niloticus* matured between 83 and 90 cm TL and males at a length of ca 65 cm. Breeding activity persisted for most of the year with a slight increase during the flood season. Spawning occurred within the lake and post-larval *Lates* were found ubiquitously in all sectors. Sex ratios varied with locality and the evidence suggests that females tended to concentrate inshore. Males were completely absent from the largest length classes and attained a maximum size of only 145 cm TL compared with 185 cm in the case of females.

The food of 1100 fish ranging from 30 to 175 cm TL was studied. Fishes were preyed on almost exclusively. *Sarotherodon niloticus* predominated in the diet of all length groups but the proportion of *Bagrus bayad* increased in larger fish. The relationship between prey size and predator size was investigated and it was found that the relative size ingested by *L. niloticus* varied from species to species.

Brief observations were made on the ectoparasites. Two species of Argulids were restricted to inshore habitats whereas the Lernaeid *Opistholernaea longa* occurred chiefly on offshore fish.

REFERENCES

COULTER, G W (1976). The biology of *Lates* species (Nile Perch) in Lake Tanganyika and the status of the pelagic fishery for *Lates* species and *Luciolates stappersii* (Blgr.) *J Fish. Biol.* *9* : 235-259

GEE, J M (1966). Nile perch studies. *Ann. Rep. E. Afr. freshw. Fish. Res. Org.* *1965* : 56-62

GEE, J M (1969). A comparison of certain aspects of the biology of *Lates niloticus* (Linne) in some East African lakes. *Rev. Zool. Bot. Afr.* *80* : 244-262

GREENWOOD, P H (1976). A review of the family Centropomidae (Pisces, Perciformes). *Bull. Br. Mus. nat. Hist. (Zool).* *29* : 4-81

HAMBLYN, E L (1960). The nile perch project. *Ann. Rep. E. Afr. freshw. Fish. Org.* *1960* : 26-32

HAMBLYN, E L (1962). Nile perch investigations. *Ibid.* *1961* : 23-28

HOPSON, A J (1969). A description of the pelagic embryos and larval stages of *Lates niloticus* (L) (Pisces: Centropomidae) from Lake Chad with a review of early development in lower percoid fishes. *Zool. J. Linn. Soc.* *48* : 117-134

HOPSON, A J (1972). A study of the nile perch (*Lates niloticus* (L), Pisces: Centropomidae) in Lake Chad. *Overseas Res. Publ.* *19* : 93 pp. London, HMSO.

HYNES, H B N (1950). The food of the freshwater sticklebacks (*Gasterosteus aculeatus* and *Pygosteus pungitius*) with a review of the methods used in studies of the food of fishes. *J. Anim. Ecol.* *19* : 35-58

KENCHINGTON, F E (1939). Observations on the nile perch (*Lates niloticus*) in the Sudan. *Proc. zool. Soc. Lond. (ser. A)* *109* : 157-168

LOUBENS, G (1974). Quelques aspects de la biologie des *Lates niloticus* du Tchad. *Cah. O.R.S.T.O.M., ser. Hydrobiol.* *8* : 3-21

WORTHINGTON, E B (1929). *Report on the fishing survey of Lakes Albert and Kyoga.* London, Crown Agents.

WORTHINGTON, E B (1932). Scientific results of the Cambridge expedition to the East African lakes, 1930-1. 2. Fishes other than Cichlide. *J. Linn. Soc. (Zool).* *38* : 121-134

WORTHINGTON, E B (1936). Scientific results of the Cambridge expedition to the East African lakes, 1930-1. No. 15. The fish of Lake Rudolf and Lake Baringo. *J. Linn. Soc. (Zool).* *39* : 353-389

THE POST-LARVAL AND EARLY JUVENILE STAGES OF Lates spp IN LAKE TURKANA

A J Hopson and A A Q R McLeod

HAMBLYN (1962) described ontological changes in the distribution of post-larval and juvenile Lates niloticus in Lake Mobutu (formerly Lake Albert). Post-larvae of 6-12 mm occurred commonly over weedy bottoms in bays. Fry of 12-20 mm had moved into shallow water close inshore and at ca 20 mm a further change in habitat to the shelter of fringing macrophytic vegetation was noted. HOPSON (1972) recorded a similar sequence of migrations in young L. niloticus in Lake Chad, with larvae of 4-8 mm TL dispersing from inshore spawning areas and spreading throughout the open waters of the lake before returning to the shore at a length of 10-12 mm.

Analgous behaviour in young Lates was observed during the present investigations but the situation has been confused by the presence of two species, L. niloticus and L. longispinis. Although it seems highly probable that representatives of both species were included in collections of post-larval and early juvenile fish, no diagnostic characters for their identification were available. The smallest juveniles which could be identified with certainty were L. longispinis of 20-30 mm. These were noted occasionally in frame and midwater trawl catches although they were well below the maximum retention length for the 19 mm cod end. The juveniles formed part of a size cohort, the larger members of which measured from 50-100 mm TL and were clearly recognisable as L. longispinis. Such fish were invariably silvery and lacked all traces of the mottled cryptic colour pattern of juveniles from inshore areas.

There is evidence, however, suggesting that all young Lates spent at least a brief period in marginal areas of the lake. Figure 11.6 shows length frequencies of Lates post-larvae combined from various series of metre townet samples representing all sectors of the lake and seasons of the year. These examples illustrate features which were common to openwater metre townet samples throughout the survey period. The modal length generally lay between 7 and 10 mm and the maximum length rarely exceeded 18 mm. There was always a sharp decrease in frequency above ca 11 mm which corresponded to the size at which young Lates moved inshore. If, as seems highly probable, the post-larval population of the open lake included L. longispinis, the evidence suggests that both species undertook a similar inshore movement.

The seasonal occurrence of Lates post-larvae in metre townet samples at Station H1 in the open lake, 2 km north of Central Island, over a period of 22 months is shown in Table 11.11. Post-larvae were present throughout the period with the exception of the final sample. Catch per effort fluctuated considerably and although peak catches were recorded in both September 1972 and 1973, no marked seasonal pattern is evident.

Length frequencies of early juvenile Lates from marginal areas of the lake are typified by results from Lodge Bay, Ferguson's Gulf (Fig. 11.6). Numbers rose steeply to a peak at a length of 24 mm and declined more steadily to a maximum of 60 mm TL. Seasonal changes in catches from Lodge Bay are shown in Table 11.12. Juveniles were present throughout the year and apart from the high January catches, numbers were comparatively uniform. Variations in mean length and size range were also relatively minor, and the results indicate that the population was in a state of flux with the smallest size classes being continually replenished by recruits from offshore post-larval populations.

Since the metre townet samples indicate that post-laarval *L. longispinis* eventually migrated inshore in company with *L. niloticus*, it is presumed that the species was represented in the shore samples. If this is correct, an offshore movement appears to have followed soon afterwards; all juveniles larger than 40 mm occurring in the inshore catches were identified positively as *L. niloticus*. As shown above, juvenile *L. niloticus* of 5-30 cm continue to inhabit inshore areas of the lake, particularly where submerged vegetation provides cover.

REFERENCES

HAMBLYN, E L (1962). Nile perch investigations. Ann. Rep. E. Afr. freshw. Fish Res. Org. 1961 : 23-28

HOPSON, A J (1972). A study of the Nile Perch (Lates niloticus (L), Pisces: Centropomidae) in Lake Chad. Overseas Res. Publ. 19 : 93 pp. London, HMSO.

THE BIOLOGY OF Lates longispinis Worth. IN LAKE TURKANA

A A Q R McLeod

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INTRODUCTION

WORTHINGTON (1932b) described two subspecies of the predatory fish *Lates niloticus* from Lake Turkana, *L. n. longispinis*, an endemic deep water small form, and *L. n. rudolfianus*, a shallow water large form. The material has been re-examined by GREENWOOD (1976) who concluded that *L. n. rudolfianus* must be regarded as a synonym of the nominate species. He proposed, however, that *L. n. longispinis* should be treated as a full species, *L. longispinis* Worthington, pending a closer examination of the relationship with *L. macropthalmus*, a similar form inhabiting Lake Mobutu (formerly Lake Albert). WORTHINGTON and RICARDO (1936) provide details of habitat, size, breeding and food in the six specimens which formed the type collection of *L. longispinis* (Also known as the dwarf perch).

Subsequent workers in the area either did not obtain specimens or failed to differentiate between the two species of *Lates* occurring in the lake.

The present study is based on a total of ca 33,000 fish examined during the period June 1972 to November 1975. They ranged from 2 cm to 64 cm in total length (TL), but the majority were adolescent or mature fish between 16 cm and 32 cm TL. Post-larval and small juvenile *Lates* spp. of 0.3-6.0 cm TL were caught in quantity during the investigation but it was not possible to distinguish between the early stages of *L. longispinis* and *L. niloticus*. Data on these small fish are analysed in a separate section (see page **1301**).

Aspects of the biology of *L. longispinis* studied during the present investigation included distribution, growth, breeding, food and ectoparasites.

MATERIAL AND METHODS

Routine bottom trawl samples provided most of the material on which this study is based but supplementary information was also obtained from other sources:

Gear	Approximate number of *L. longispinis*
Bottom trawl	31,000
Bottom, midwater and surface set gillnets	1,200
Boris midwater trawl	820
Frame trawl	300

Occasional individuals were also caught in beach seines. Trawl samples were examined immediately on board R V HALCYON except when accurate weight measurements were required. These were made in the shore laboratory within four hours of capture. Lengths of unweighed individuals were recorded to the nearest cm below and weighed individuals were recorded to the nearest 0.1 cm below. All lengths cited in this text are total lengths (TL), measured from the anterior margin of the upper mandible to the distal end of the medium caudal fin ray.

Weights were recorded to the nearest gram, and relate to the entire fish. Data on gonadial state, food, and in many cases ectoparasites, were also obtained.

The length frequency distribution of *L. longispinis* examined from bottom trawl catches obtained within the Ferguson's Gulf area (Grid squares K1-K3, L1-L3, M2-M3 - see Fig. 8.1) is shown in Figure 11.7a and is representative of the lake as a whole (see below). The bimodal length frequency distribution is the result of a bias caused by samples for October 1972, August and September 1973 which were considerably larger than the monthly average.

The bottom trawl with which most of the material was caught was equipped with a 38 mm stretched mesh cod end and data in Table 11.13 indicate that the mean retention length for *L. longispinis* in this net was approximately 7 cm. Thus although the low proportion of smaller fish in the samples (Fig. 11.7a) was partly due to escapement, the results indicate that the recruitment of the younger individuals into the trawling areas was incomplete. This view is supported by evidence from the 19 mm stretched mesh cod end of the frame trawl (Fig. 11.7b) in which there was a similar dearth of smaller fish. The rarity of *L. longispinis* in open water samples of lengths of less than 4 cm TL is probably due to a tendency for smaller fish to inhabit marginal areas of the lakes (see page 1301).

DISTRIBUTION

Lates longispinis was found to occur throughout most of the area of Lake Turkana but was primarily established at and below the depth zone where the midwater scattering layer impinged on the bottom. The species was virtually absent from inshore regions, except under conditions of extreme turbidity, and uncommon in the deepest parts of the lake. Various types of fishing gear yielded good catches of the species, principally bottom and midwater trawls, but the frame trawl, gillnets and occasionally shore seines also retained specimens in lesser quantities.

DEMERSAL POPULATION

The most detailed information on the distribution of *L. longispinis* was obtained by bottom trawling and stations records, grouped on a seasonal basis, are presented on charts in Chapter 8, Figures 8.15 a-c. The charts indicate that densities of demersal *L. longispinis* were greatest in the Northern and Central Sectors (see Fig. 8.1) and that the population was not uniformly distributed. In the Southern Sector catches were much lower and tended to be more consistent than those made further north. *L. longispinis* was most abundant at intermediate depths on the west side of the lake north of Audache, where values of catch per unit effort (CPE) as high as 1500 kg/hr were recorded. Seasonal movement throughout the length of the lake was not apparent. The occurrence of an annual inshore movement of the population coinciding with flooding in the River Omo is discussed below.

The depth distribution of *L. longispinis* in bottom trawl catches is summarised in Figure 8.5 which demonstrates that peak densities occurred in the 20-30 m depth zone in the North and Central Sectors and in the 30-40 m depth zone in the Southern Sector. Relative abundance fell to low levels in the inshore zone as well as in the deeper parts of the lake. Lates longispinis was rarely the predominant fish in bottom trawl catches but in the 20-30 m zone of the Central Sector the species formed an average of ca 35% of the total catch by weight.

Figure 11.8 provides a model for the depth distribution of all L. longispinis by locality and size. Mean catch per unit effort for all quantitative bottom trawl catches are presented as No/hr and kg/hr per 5 cm length class in twelve depth zones for each of the three main sectors of the lake. In the inshore 0-5 m zone and in water of greater than 70 m depths all size classes were generally present.

Over most of the range of L. longispinis the size structure of populations was remarkably constant. However, fish of 20 to 35 cm TL were slightly more predominant in the 25 m depth zone in all sectors and in the deepest part of the lake only fish of 10 to 25 cm were recorded. Highest catch per unit effort of all size classes appeared in the 15 to 25 m depth zone in the Central Sector. Maximum CPE in the Northern and Southern Sectors were considerably lower, occurring in 25 m of water at the north end of the lake and 30 m in the south. Mean CPE for each size class in all depth zones of each sector are presented in Table 11.14. Total mean CPE for each depth zone for six sub-sectors of the lake are summarised in Figure 8.4 and combined in Table 8.5.

Bottom-set gillnets provided valuable additional evidence on the distribution of L. longispinis in the Ferguson's Gulf area. The results, summarised in Figure 8.62 corroborate the evidence provided by the bottom trawl survey and clearly demonstrate the dearth of demersal L. longispinis above the midwater scattering layer and the presence of moderate quantities below. The feasibility of commercial gillnet fisheries for L. longispinis is discussed on page 1312.

PELAGIC POPULATION

The higher proportion of everted stomachs in bottom trawl hauls in offshore areas (Table 11.15) indicates that with increasing sampling depth, L longispinis were also caught in deeper water. At depths greater than 60 m there was a reduction in the evertion rate in all dwarf perch with the exception of the 25-30 cm size-class, indicating that a high proportion of fish were caught off the bottom during the paying in and paying out of the trawl. No further conclusions can be drawn as evertion rate depends on a variety of factors including size of fish, state of fullness of the stomach, vertical ascent rate as well as the depth at capture. Further indirect evidence of the pelagic nature of a proportion of the population of L. longispinis is provided in the section on diet, see below.

Direct evidence as to the diurnal pelagic habits of the dwarf perch was provided by frame trawl and Boris midwater trawl studies. A cod end of 19 mm stretched mesh was used in both these trawls, compared to the 38 mm stretched mesh used in most bottom trawl hauls.

Size selection curves for all L. longispinis caught during the months of August and September in the frame trawl are compared with total bottom trawl catches for the same months when a 19 mm stretched mesh over-bag was employed (Fig. 11.9a and b). Although the results are not for the same years a comparison of the size selection curves for the two nets is made valid by the annual recruitment pattern of

L. longispinis (see below). The bimodal length frequency distributions of the two samples are similar. Mean size of fish caught in the bottom trawl was 20.9 cm TL (SD = 8.12 cm) and only moderately greater than a mean of 16.9 cm TL (SD = 5.8 cm) for the frame trawl catch. The relative sizes of the two peaks of the length frequency distributions show only a slight skewing to the left in frame trawl samples. These effects are more likely to be due to differing year class strengths than to differences in the size selectivity of the two nets. The shorter size range of 8-31 cm TL noted in the frame trawl samples (cf 4-50 cm TL in the bottom trawl) probably resulted from a smaller sample size.

The horizontal distribution of L. longispinis determined by the use of full water column oblique frame trawl hauls during two cruises, in July 1974 and September 1975, is presented in Chapter 8, Figure 8.40. The results show that L. longispinis occurs principally in water shallower than 60 m, but is found irregularly at all depths, with many hauls failing to record the species. A series of horizontal tows in the midwater scattering layer with the Boris midwater trawl between September and November 1975 shows that the density of pelagic L. longispinis was highest in inshore areas especially on the west coast but the species occurred at nearly all stations except in the southern basin (Fig. 8.25). Catches were low in the area to the west of Allia Bay, with the higher densities north of Koobi Fora corresponding to the east shore counter-current (see Chapter 1). A similar pattern of distribution was noted in Alestes baremose and A. minutus, the principal components of the scattering layer, which form an important part of the diet of pelagic L. longispinis (see below).

The vertical distribution of L. longispinis is demonstrated by a series of frame trawl samples taken near Longech in April and May 1974 at a lake depth of 25-30 m when the scattering layer was situated at a depth of 10-18 m (Fig. 8.31). The species was absent from the surface layers but was recorded occasionally within the scattering layer and became more common in the water column below. Frame trawl data for the period September to December 1973, when the scattering layer lay closer to the surface at depths of 4 to 10 m, indicate that the vertical range of L. longispinis had extended upwards (Fig. 8.33). Results from lake depths of over 30 m obtained during the same period show that under such circumstances L. longispinis was almost totally pelagic in habit (Fig. 8.34), dispersing downwards from the scattering layer to a depth of 20 m with only occasional individuals recorded at greater depths.

Adequate numbers of pelagic L. longispinis for length frequency analysis were obtained in the Boris midwater trawl. Table 11.16 presents the length frequency of pelagic L. longispinis recorded in four lake depths. All size classes from 5 to 55 cm TL were observed, and only fish of greater than 40 cm TL were absent at lake depths of over 50 m. The 10-20 m size class dominated catches in water deeper than 50 m but further inshore the relative proportions of the size classes did not greatly differ between depth zones. Vertical zonation of size classes in the 30-50 m depth zone is recorded in Table 11.17. In midwater all size classes of between 5 and 40 cm TL were found in all depth zones and at depths of over 11 m occurred in the same relative proportion. At depths of less than 11 m fish of between 30 and 40 cm TL were relatively less common. Comparison with bottom trawl catches is not simple, due to a difference between the cod end meshes employed. The largest fish recorded, of between 45 and 55 cm TL, were only present in the bottom trawl, and the smallest pelagic size class of 5-10 cm TL was absent in the demersal sample. The latter is certainly an effect of escapement, the mean retention length of L. longispinis being about 7 cm in the bottom trawl 38 mm stretched mesh cod end. It is probable that all except the largest size classes were distributed in equal proportions throughout the water column from the scattering layer downards.

The only records of L. longispinis occurring close inshore during the present investigations were from Ilaret at the height of the flood season in October 1974 where the lake was very turbid. Nine fish of 7 to 44 cm TL, heavily infested with lernaeid parasites, were caught by beach seine. During the same period bottom set gillnets of between 5 and 10 inches stretched mesh, set in shallow water close inshore, caught fourteen L. longispinis of between 15 and 50 cm TL, similarly infested with parasites (Table 8.25b).

Midwater gillnets caught only limited numbers of L. longispinis (Tble 8.23) and results compare favourably to those obtained by active fishing gear. Catches were greater below the scattering layer and reached a maximum where the scattering layer impinged on the bottom. The occasional occurrence of L. longispinis in surface set gillnets (Table 8.26) proves that the species at times migrated into the surface waters at night (see below).

DIEL VERTICAL MIGRATION

A 24 hour frame trawl station conducted off Longech Spit in 28 m of water during April 1974 (Fig. 8.35) demonstrated that the relative positions of L. longispinis and the species comprising the scattering layer, principally A. ferox, remained unchanged throughout the entire study period. During the hours of daylight L. longispinis was confined to the bottom 4 m while the scattering layer lay at a depth of 13 to 18 m. With the onset of darkness the scattering layer rose, with A. ferox concentrating in the surface 8 m by midnight. At the same time L. longispinis migrated upwards and by midnight the population was dispersed at a depth of between 8 m and the bottom. With the onset of daylight, downward migration occurred until the daytime pattern of depth distribution in the two species was re-established. The pattern of vertical migration of L. longispinis agrees with models reviewed by CUSHING (1951) and LONGHURST (1976) and is discussed at length in Chapter 8.

SEASONAL MIGRATIONS

The transparency of Lake Turkana was greatly influenced by sediments deposited by inflowing rivers, particularly the River Omo, but also the River Turkwell, the River Kerio and local ephemeral streams (see Chapter 1).

This changing environment exerted a strong influence on the depth distribution of L. longispinis. Table 11.18 lists the monthly CPE in numbers per hour caught in five depth zones for all quantitative bottom trawl hauls within the Central Sector. The relative proportions of juveniles, females and males occurring throughout the year is summarised in Figure 11.10. L. longispinis was only occasionally trawled from depths of over 50 m and these individuals were almost certainly pelagic fish caught during paying in and paying out of the net. The relative proportion of L. longispinis present in the 30-50 m depth zone was greatest during the months June to August when the water of the Central Sector attained its maximum transparency. L. longispinis moved closest inshore during the months of November and December, a period of high turbidity, with over 40% of the mature fish occurring in depths of less than 10 m. During the first six months of the year and during September and October L. longispinis was distributed principally between the 10 and 30 m contours. In January and February increasing water transparency resulted in an offshore movement of the population. The River Turkwell, River Kerio and local rivers flowed at times strongly into the lake during March, April and May and the turbidity caused limited local inshore movement of the population. After this period, rapidly clearing water resulted in an offshore movement into deeper water. In all months the relative proportions of immature, female and male L. longispinis in any one depth zone tended to be similar.

Inshore movement of L. longispinis during the flood season in the Northern Sector resulted in occasional individuals being caught in the shore seine and gillnets set close inshore. During this period L. longispinis failed to occur at either trawl stations or in experimental gillnets sited off the Omo delta. Transparency in the Southern Sector remained high throughout the year and within this area no evidence was obtained for the movement of L. longispinis between different depth zones.

DISCUSSION

From the above results it can be seen that the distribution of Lates longispinis is controlled by three factors: the depth of water, its transparency and the availability of food. The absence of the smallest and largest size classes of L. longispinis from bottom trawl samples at extremes of distribution is probably an effect of small sample size. At depths greater than 50 m L. longispinis was a pelagic fish with only occasional demersal individuals recorded in the bottom trawl. The inshore limit of the scattering layer represented the minimum lake depth to which L. longispinis penetrated. In the pre-flood season L. longispinis was evenly dispersed between the scattering layer and the bottom as far offshore as the 50 m contour; this figure was reduced to about 30 m during the flood season. L. longispinis could be trawled with both pelagic and demersal gear. The species seemed to be adapted to a particular light regime, and when light levels rose or fell below a particular threshold, vertical and lateral movement occurred until a suitable environment was found. Avoidance of water of low conductivity was also noted. Density of L. longispinis tended to parallel changes in density of the scattering layer formed by the prey species Alestes ferox and A. minutus even though L. longispinis lived at greater depths.

High densities of the prey species of prawn, Caridina nilotica and Macrobrachium niloticum also tended to occur in the same localities (see Chapter 4, page 253). Stock densities of L. longispinis in terms of trawlable catch are presented in the chapters devoted to the various types of sampling gear used.

The evolution of L. longispinis in Lake Turkana has been paralleled by the evolution of L. macrophthalmus in Lake Mobutu (formerly Lake Albert) (WORTHINGTON, 1929; HOLDEN, 1967) and L. mariae in Lake Tanganyika (COULTER, 1976). All these endemic species principally inhabit the offshore and pelagic zones of their respective lakes.

COMMERCIAL FISHERIES

Experimental gillnet data (see Chapter 8) show that yields of L. longispinis in both bottom and midwater nets were low, and the species was virtually absent from surface set nets.

The highest mean catch per unit effort recorded was 15 kg per 100 yards of bottom set 3" net set in 19 m of water east of Longech Spit. In this case L. longispinis comprised only 18% of the total catch and often this species comprised an even lower proportion of the total catch. The remainder of the catch was frequently composed of Synodontis schall and the sharp pectoral and dorsal spines in this fish rapidly destroyed the nets in which it was entangled. Yields of L. longispinis were highest in bottom or midwater set 3 inch gillnets in an area extending a short distance offshore from the point where the scattering layer impinged on the bottom. Mean size selection data recorded from eleven sizes of experimental gillnets (Table 11.19) show that the 3 inch nets tended to take L. longispinis at about the size of first maturity (see page 1317). L. longispinis was beginning to occur in commercial gillnets during 1975 as a result of reduction in the size of gillnets employed, but catches did not form a significant part of the total yield.

A sample of 43 L. longispinis with a mean length of 36 cm, weighing a total of 19 kg yielded 4.5 kg of palatable fillets.

GROWTH - MORTALITY

GROWTH

Growth checks on the scales of L. longispinis proved to be laid down irregularly and were of no value as a key to age determination. The lack of seasonal checks is probably an effect of the stable environment in Lake Turkana, where the annual range of water temperature is only 2° C. Samples of L. longispinis obtained by trawling in the Ferguson's Gulf area between July 1972 and August 1975 show, however, a regular pattern of growth in size cohorts, a requirement for growth determination by Petersen's method of analysis (PETERSEN, 1892). The length frequency distribution of female and male L. longispinis sampled at monthly intervals, is shown in Figure 11.11. The monthly pattern of length frequency distribution shows no marked sexual difference.

Comparison between successive months in each sex shows that the modes progress to the right, suggesting periodic recruitment and a steady rate of growth. The rate of growth is summarised in Figure 11.12, in which the median length for various modes in each sex for each month is plotted against time. There is no evidence to suggest differing growth rates between females and males of less than 30 cm TL. Mortality in males of greater than 30 cm TL is high, especially in the first half of the year.

Combined recruitment and growth data for the total trawl sample from the Ferguson's Gulf area (Fig. 11.13) suggest that five year classes occurred in catches during the study period. The proportion of various age groups in the samples differs from month to month with the result that mortality rates were difficult to estimate directly. Summing and averaging the medians of the modes present in each monthly

monthly sample, assuming the same birth date in each year, gives an approximate estimate of mean growth rate (Table 11.20 and Fig. 11.14). No allowance for year class strength has been made. Fitting a growth curve to these values proved difficult. The most satisfactory solution was provided by a Walford Plot (RICKER, 1975) which gives a von Bertalanffy growth model of

$$L_t = L_\infty \ (1 - e^{-K(t-t_o)})$$

where l_t is length in cm after time t in years from a hypothetical birth date t_o, L_∞ the mean asymptotic length in cm, and K a constant determining the rate of decrease of length increments. The derived parameters for L. longispinis were $L_\infty = 70.4$; $K = 0.31$; $t_o = -0.063$ from a birth date in December. The growth model for L. longispinis generated by using these values has been plotted in Figure 11.14. The high value of L_∞ is suggestive of neotonic development in L. longispinis.

Fish of over 30 cm TL appear to suffer a heavy mortality in the first half of the year, which would account for the lack of large L. longispinis occurring in the lake. This length corresponds with the length at first maturity (see below).

MORTALITY

Methods of estimating mortality rates of tropical fish where mean length and length at first capture are known are presented by SSENTONGO and LARKIN (1973). Their method requires that the investigated fish population has a continuous pattern of recruitment. In L. longispinis the rate of recruitment into the population as shown in Figure 11.13, and by the breeding activity (see below), both provide evidence of an extended breeding season, and the value of mortality rate calculated below is probably not greatly in error. A mean length of capture of 22.4 cm (SD = 7.92 cm) is obtained from monthly values of length frequency composition of trawl catches in the Ferguson's Gulf area between June 1973 and May 1974. In order to compensate for differing sample size, each monthly sample (Fig. 11.13) was weighted down to 100 fish. Consequently the standard deviation is probably an overestimate.

The formula for the estimation of total mortality given by SSENTONGO and LARKIN (op. cit.) is:

$$\widehat{(Z/K)} = \frac{n}{n+1} \cdot \frac{1}{y-y_c} \qquad (1)$$

$$\text{Standard deviation } \widehat{(Z/K)} = \sqrt{\frac{(n)^2}{(n+1)} \cdot \frac{1}{n(y-y_c)^2}} \qquad (2)$$

$$y_c = -\ln\left(1 - \frac{l_c}{L_\infty}\right) \qquad (3)$$

$$y = -\ln\left(1 - \frac{l_m}{L_\infty}\right) \qquad (4)$$

where Z is the mortality rate, l_m the mean length at capture in cm, l_c length at first capture in cm, and n the sample size. l_c has been estimated as 7 cm from the mean retention length of the 38 mm stretched mesh cod end (see page 586). Inserting the growth parameters obtained for L. longispinis in formulae (1) and (2) gives a value of $(\widehat{Z/K})$ = 3.59 (SD - 0.10). The mortality rate of L. longispinis derived from (1) gives a value of Z = 1.11 using the value K = 0.31 obtained earlier. Since fishing mortality is virtually zero, the derived value of total mortality will also be an estimate of natural mortality in L. longispinis. This value has been used together with stock estimates to produce values of yield in Chapter 13.

LENGTH-WEIGHT RELATIONSHIP

The relationship between length and weight in fish is usually represented by the formula:

$$w = ul^v$$

where w = weight in gm, l = total length in cm, u and v are constants. The length-weight relationship for 698 immature fish ranging from 2 to 28 cm TL, 1109 females of 16 to 55 cm, 818 males of 14 to 52 cm and 818 unsexed fish of 14 to 62 cm were recorded in the present investigations. Values of u and v were obtained by fitting a geometric mean function linear regression to the logarithmic form of the above expression (RICKER, 1973). Values for u and v are summarised in Table 11.21.

CONDITION FACTOR

Values of the condition factor (k) for L. longispinis were obtained from the length-weight relationship of all fish examined, using the formula

$$k = \frac{100w}{l^3}$$

Mean values of k have been worked out for each sex in 5 cm size classes (Table 11.22). There was no significant difference in $\bar{k}$ between sexes in any one size class, and values have been combined to produce a mean k for the sample. A plot of $\bar{k}$ and the 95% confidence limits for each 5 cm size class is produced in Figure 11.15. There was a marked decrease in the value of $\bar{k}$ with increasing total length. Thus $\bar{k}$ fell from 1.27 in the 0 cm size class to 0.92 in fish of 45-50 cm TL. Larger values of $\bar{k}$ recorded in the 50-60 cm size class are not significant. The trend resulted from allometric growth, due to an increase in the relative length of the caudal peduncle. In other populations of Lates spp. values of $\bar{k}$ generally increased with size.

During the present investigation values of $\bar{k}$ in Lates niloticus were found to increase from 1.05 in fish of 30-40 cm TL to 1.18 in fish of 50-60 cm TL. COULTER (1976) working on Lates spp. in Lake Tanganyika found in L. mariae values of k tended to remain constant in adults after rising from a lower value in juveniles.

Studies of the seasonal variation in the value of k have been confined to juveniles and adults of over 25 cm TL. Mean monthly values of k for juveniles and males and females combined from all L. longispinis examined between July 1972 and February 1974 have been plotted in Figure 11.16 a-c together with the 95% confidence limits about the mean. In the juvenile population $\bar{k}$ increased from 1.02 in February to a maximum of 1.11 in April. During May and June, values of $\bar{k}$ fell to a minimum of 0.97 and remained at about 1.0 for the rest of the year. The rise in the value of $\bar{k}$ in the first four months of the year corresponds to the recruitment of small size classes into the population (Fig. 11.13). The drop during April, May and June relates to the high mortality of the smaller size classes and the growth of the remainder with a corresponding reduction in the value of $\bar{k}$. The adults (Fig. 11.16 b and c) underwent a similar cycle with a peak value of $\bar{k}$ in April of 1.01 due to a recruitment of adolescent fish into the population. Their subsequent growth explains the falling value of $\bar{k}$ to a minimum of 0.91 in September. Trends in the value of $\bar{k}$ for fish of 35-40 cm TL, a size at which most *L. longispinis* have spawned at least once (see page 1317), is confused by small sample size. 16 females of between 35 and 40 cm TL were at a minimum observed mean $\bar{k}$ of 0.91 (SD = 0.027) in March 1973, and a further five at maximum observed value of $\bar{k}$ of 1.00 (SD = 0.087) in the succeeding month. This relates to a recovery from a spent condition in post-breeding stock.

BREEDING

Information on the breeding cycle of *Lates longispinis* during the present investigation has been obtained primarily from the examination of bottom, midwater and frame trawl catches. Of the 15065 *L. longispinis*examined, 5810 were females of 13-58 cm TL, 4253 were males of 13-57 cm TL. The remainder were immature fish of between 2-24 cm TL. The determination of sex and maturity stage were carried out macroscopically.

MATURITY STAGE

The assessment of the gonadial stages of *L. longispinis* were based on the method described by HOPSON (1972) for the Lake Chad population of *L. niloticus*. The maturity stages of *L. longispinis* are as follows:

Females

Stage 1	Immature; ovaries a pair of thin transparent strands running longitudinally along dorsal wall of body cavity; sexes undistinguishable macroscopically.
Stage 2	Virgin/Resting; ovary white or pink, translucent, smooth, cylindrical. Cells colourless, transparent, maximum diameter 0.1 mm, vascularisation slight.
Stage 3	Early maturing; ovary pink or red, translucent, pear shaped in cross section. Cells up to 0.2 mm in diameter, tissue well vascularised, microscopic fatty yolk droplets visible.
Stage 4	Late maturing; ovary pink or red with small yellow opague ova clearly visible, pear shaped in cross section. Ova not of a uniform size, varying from 0.1 to 0.5 mm diameter bound in a matrix of smaller clear follicular cells.

Stage 5	Ripe; ovary yellow or buff, opaque, ova of nearly uniform size visible through superficial membrane, pear shaped in cross section, large blood vessels on surface. Ova 0.6 mm in diameter bounded by a follicular matrix of cells of less than 0.1 mm diameter.
Stage 6	Running; ovulation in progress; a quantity of opaque yellow or buff ova typical of the Stage 5 condition still bound in a matrix of follicular cells, together with a larger quantity of ripe ova lying loose in the lumen. Ripe ova translucent yellow-green in colour, 0.65 mm in diameter with a single oil globule 0.4 mm in diameter. Slight external pressure causes ripe ova to be extruded from the vent.
Stage 7	Spent; ovaries loose and flabby containing loose follicular tissue rich in blood with a few scattered residual Stage 5 ova.

Recovering females revert to Stage 2 condition. These individuals were sometimes recognisable by the presence of small opaque brown bodies of irregular shape scattered through the ovarian tissue and just visible macroscopically under conditions of good illumination. These bodies apparently represent the corpora lutea and were occasionally recognisable in Stage 2-4 ova. Residual yolky eggs were also occasionally visible in Stage 2 ova.

Males

Stage 1	Immature; testes a pair of thin transparent strands running longitudinally along the dorsal wall of the body cavity; sexes indistinguishable macroscopically.
Stage 2	Early developing; testes semi-transparent, grey or white occasionally pinkish, narrow and flattened.
Stage 3	Late developing; testes semi-transprent, grey, white or pink, often well vascularised and flattened. Occupying relatively more of the body cavity than Stage 2 testes; no milt when cut.
Stage 4	Mature resting; testes opaque, white or pink, often well vascularised, firm, edges somewhat flattened; slight milt exudes from lumen when cut.
Stage 5	Mature ripe; testes opaque white or pink, soft, swollen, the edges well rounded; copious milt when cut.
Stage 6	Running; similar in appearance to Stage 5 but milt running freely from vent when slight external pressure applied to fish.
Stage 7	Spent; testes flaccid and pink; when cut lumen large and exuding clear fluid and a little milt.

In males, spawning was probably followed by a rapid recovery to a resting Stage 4, with a small proportion reverting to resting Stage 3.

SIZE AT MATURITY

No regional differences were observed in the length at first maturity in L. longispinis and data from all trawl catches are presented in Tables 11.23-24. The results indicate a steady rate of development in the females (Table 11.23) with no sign of maturation in fish of less than 17 cm TL. The smallest ripe (Stage 5) female measured 23 cm TL and the proportion of ripe fish rose in succeeding length classes to become steady at lengths above 33 cm TL, indicating that most females had matured. The length at 50% maturity in female L. longispinis was thus approximately 30 cm TL. The smallest running and spent females measured 25 and 30 cm TL respectively. The proportion of ripe females fell at lengths above 42 cm indicating that larger females underwent a longer post-spawning resting and recovery period than smaller fish.

The results of examination of ova for the presence of corpora lutea or residual eggs are presented in Table 11.25. Evidence suggesting that spawning had previously occurred was first observed in a female of 28 cm TL and the percentage of previous spawners rose steadily with increasing length to stabilize at 40 cm TL. Due to the difficulty of observing corpora lutea under field conditions, the observed proportion of previous spawners never rose above 60%.

In male L. longispinis (Table 11.24) no sign of maturation was observed in fish below 17 cm TL and the smallest ripe individual measured 21 cm TL. The percentage of ripe males became steady at lengths above 30 cm TL, indicating that the length at 50% maturity in the population of males was reached at 28 cm TL. The smallest running/ripe and spent males measured 29 cm TL and 32 cm respectively. As in females there was a reduction in the proportion of ripe males at lengths of over 42 cm, indicating a longer resting stage in larger mature individuals.

In terms of age both males and females tended to commence spawning when two years old and all females had spawned at least once by an age of three years.

The tendency for males to mature at a smaller size than females has been noted in other cases in the genus Lates. Thus in L. macrophthalmus, endemic to Lake Mobutu (formerly Lake Albert), GEE (1965) recorded a length at first maturity of 21 cm TL in males compared with 24 cm TL in females. COULTER (1965) working on L. mariae, endemic to Lake Tanganyika, estimated a length at 50% maturity for males of 44 cm compared to 49 cm in females. For L. niloticus in Lake Chad HOPSON (1972) showed that males reached 50% maturity at 50 cm TL while females attained a similar state at 60-65 cm TL. A difference between length at first maturity was also found in the Lake Turkana population of L. niloticus, with 50% maturity in males and females occurring at 65 and 85 cm respectively.

SEASONAL CHANGES IN MATURITY

Data relating to the maturity stages of L. longispinis of over 30 cm TL caught by trawling in the three main sectors of the lake during the study period were grouped by sex on a monthly basis. No significant difference could be found between regions or between years and data for all years have been combined. The monthly proportions of each maturity stage in females is listed in Table 11.26 and the same data for males is listed in Table 11.27. The results suggest that spawning is at a peak between January and March, but that breeding activity continues at a lower level throughout the remainder of the year. The increase in the proportion of Stage 2 females and previous spawners in November (Table 11.26) shows that the spawning peak starts as early as October. Maximum proportions of Stage 2 females and previous spawners occur in April showing that spawning is largely over by the end of March. Males show a similar pattern in the last two and first three months of the year (Table 11.27) but the rapid recovery to Stage 4 and Stage 5 condition obscures any prolonged period of reduced activity beyond the annual minimum in April. The recorded proportion of Stage 2 males reached a peak in June due to recruitment of adolescent stock and the mortality of the larger size classes (Fig. 11.11b). A similar peak in the proportion of Stage 2 females occurred earlier, in April, (Table 11.26), due to a post-spawning peak of recovering fish. Female post-spawning mortality was not as severe as it was amongst the males (Fig. 11.11a).

Densities of post-larval and juvenile Lates (see page 1301) were consistent with continuous spawning. Post-larval Lates of 6-10 mm were observed in metre townet hauls in all sectors of the lake and at all times of the year. Since breeding of L. niloticus was continuous and at a nearly uniform level throughout the year, it is probable that for most of the year the early stages of Lates observed were principally those of L. niloticus.

Spawning in L. longispinis was probably correlated with physical or chemical changes introduced by the Omo flood waters. The delay between the start of the flood season and the actual spawning peak shows that environmental changes did not induce spawning behaviour but probably initiated the maturation of the gonads. It is of note that the spawning of Alestes minutus and A. ferox, fish species forming the principal fish prey of pelagic L. longispinis (see page 1322), occurs during the start of the flood season and before spawning activity increases in L. longispinis. Population densities of the small characins are thus high during the period when populations of L. longispinis are augmented by large scale recruitment of juvenile fish.

SPAWNING GROUNDS

During the present investigations, concentrations of Lates eggs were never found, although tows with coarse plankton nets were made in the inshore and marginal areas of the lake. Solitary eggs were, however, occasionally collected during routine zooplankton surveys conducted with a five inch Clark-Bumpus net (see Chapter 1). Post-larvae of lengths greater than 5 mm were regularly obtained from metre townet catches, and their lakewide distribution (Fig. 8.58) indicate that spawning sites of one or both species of Lates occurring in the lake was not localised.

Direct evidence of spawning was obtained in 15 bottom trawl hauls and one haul with a midwater trawl on the bottom. Nineteen running-ripe (Stage 6) females occurred in 14 of the tows, and fifteen running-ripe males in 6 tows. Three tows caught running-ripe females and males simultaneously. Two of these tows (one in March 1974 and one in April 1974, both north of Longech Spit) also caught spent individuals of both sexes. A further two tows caught spent males together with running-ripe L. longispinis, one together with running males, the other together with running females. One running-ripe female was also caught in a bottom set 4 inch gillnet.

Of the 17 stations in which running-ripe L. longispinis occurred, two were in the Northern Sector, fourteen in the Ferguson's Gulf area, and one was in the Central Sector outside the Ferguson's Gulf area. One running-female was caught on the east side of the lake, in 12 m of water north of Koobi Fora; the remainder of the spawning fish were caught on the west side of the lake between Longech Spit and Lowarangak. Both sexes were caught at an average lake depth of 23 m. A single running male and female were caught together at a depth of 54 m southwest of Central Island. A solitary Stage 6 male occurrred in 6 m of water off the end of Longech Spit, and a solitary Stage 6 female in 10 m of water north of Lowarangak. The remainder of the running-ripe fish from the west side of the lake were caught at lake depths of between 19 and 28 m.

Although spent and previous spawning females were caught in all sectors, it is likely that the main spawning areas for L. longispinis were situated on the west side of the lake, between Audache and the Omo delta. Optimum depths for spawning appear to have varied from 20-30 m in more southerly areas to 10-20 m in turbid northerly waters.

SEX RATIO

The sex ratio (number of females per 100 males) was calculated for all demersal L. longispinis for each length group, in four depth zones, from each of the three main sectors of the lake (Table 11.28). The ratio of females to males varied both with size of fish and locality. At lengths of less than 20 cm TL the sex ratio did not significantly differ from 1:1 except in the 10-20 m zone in both the Northern and Central Sectors, where there was a predominance of females.

In L. longispinis of between 20-40 cm TL in the 0-10 m depth zone, the number of males was significantly greater than the number of females only in the Southern Sector. At depths greater than 10 m, there was an overall trend for females to dominate the 20-40 cm length group, except at certain localities. In the 10-20 m depth zone, females did not significantly outnumber males, particularly in the inshore zone in the Northern Sector. In the 20-30 m zone in the Northern Sector, females outnumbered males at lengths of between 28-40 cm TL, but in the Southern Sector the ratios did not differ significantly from a 1:1 ratio. In the Central Sector, males of between 26-36 cm TL considerably outnumbered females in the 20-30 m depth zone, but at depths of over 30 m there were significantly more females than males.

In larger fish of over 40 cm TL, females predominated significantly at all depths in all sectors, except in the 0-10 m zone in the Northern Sector.

The preponderance of females in the larger size classes, and their greater maximum size, are probably the result of sexual differences in mortality. Seasonal variation in the sex ratio of L. longispinis trawled from within the Ferguson's Gulf area during the present investigation are listed in Table 11.29. The samples are necessarily smaller than those examined from the lake as a whole but there is no marked difference between the annual mean for the Central Sector (Table 11.28) and the March-June sex ratios in the Ferguson's Gulf area (Table 11.29). At Longech in the early flood season, the predominance of males present in the 24-36 cm length group shifted inshore to the 10-20 m depth zone. During the period of peak spawning between November and February (see above) there was not a significant number of males over the 1:1 ratio in any depth zone, and the overall dominance of females increased slightly. This was certainly due to a higher post-spawning mortality amongst the male population of L. longispinis, compared to the female population.

FOOD

The stomachs of Lates longispinis were inspected during the regular examination of trawl catches on board R V HALCYON. The recording of ingested items was based on the volumetric method described by HYNES (1950). Stomach fullness was graded on a 16 point scale from 0/16 (empty) to 16/16 (full). The total number of points awarded to all food items was divided amongst the individual food items in proportion to their volume. Details of prey size were also recorded. A record of everted stomachs was kept for all stations, since fish in such condition were common in deep water trawls. This phenomenon was a result of expansion of the swim bladder due to decompression. The high abdominal pressures generated were sufficient at times to force the stomach up through the oesophagus into the buccal cavity. The depth distribution of L. longispinis with everted stomachs has already been discussed on page 1308.

Records of food were obtained for a total of 2225 L. longispinis ranging from 2 to 58 cm TL, three quarters of which were caught in the bottom trawl and the remainder in the midwater or frame trawls. Distinct differences were found between the diet of demersal and pelagic L. longispinis. Seasonal, regional and diel variations in diet and feeding behaviour were also identified.

FOOD OF DEMERSAL Lates longispinis

For the purposes of this study it has been assumed that all L. longispinis caught in the bottom trawl were demersal in habit. It was, however, probable that a proportion of the fish taken at deeper stations were caught while the trawl was passing through the midwater regions. The error introduced by this sampling imprecision is small compared to the difference in diet that occurred between demersal and pelagic L. longispinis.

The data on the diet of L. longispinis from all bottom trawl hauls have been analysed on the basis of length in Table 11.30. The number of points scored by each food item is expressed as a percentage of the total points recorded by all food items in each length class examined. Percentage fullness was obtained by expressing the total score gained by all food items as a proportion of the maximum possible score from fish with stomachs in situ. Fish with everted stomachs have not been included in this study. The results (Table 11.30) demonstrate that the diet of demersal L. longispinis consisted chiefly of prawns and fish, with insects forming less than 3% of the total diet even in the smaller size classes. A marked change of diet is evident with increasing size. Fish of less than 35 cm TL fed principally on prawns, with the 0-10 cm class feeding almost exclusively on Caridina nilotica. Lates longispinis of 10-35 cm TL preyed principally on prawns, largely

Macrobrachium niloticum, with fish forming the remainder of the diet. In *L. longispinis* of over 35 cm TL fish formed the bulk of the diet, and specimens over 50 cm TL fed exclusively on fish. Most of the fish species ingested including *Barbus turkanae*, *Bagrus bayad*, *Chrysichthys auratus* and *Haplochromis macconneli*, were demersal in habit, suggesting that predation had occurred near the lake bed. Pelagic species such as *Alestes ferox* and *A. minutus* were only found regularly in the food of the larger size classes. That such fish are eaten in quantity by free swimming *L. longispinis* was demonstrated by the advanced state of digestion of many of the identifiable fish remains, providing that the species had not been taken during the short time period of trawling when prey and predator could have been brought into close proximity within the confines of the net. Most trawl hauls were conducted during the hours of daylight, and since fish were eaten principally during the hours of darkness (see below), the time gap would account for the advanced stage of digestion observed in the fish component of the diet. The percentage of empty stomachs in the observed size classes ranged from 0% to 45% (Table 11.30) but showed no tendency to change with size in cases where an adequate number of *L. longispinis* were sampled. Relative fullness of stomachs ranged from 13% to 41% but was also independent of size.

Large numbers of food items, all at the same stage of digestion, were frequently observed in stomachs of individual fish, suggesting that *L. longispinis* fed by a series of repeated attacks separated by a long time interval from the next feeding session. A sample of 17 *L. longispinis*, all of which had food in their stomachs, was obtained by bottom trawling near Longech Spit during June 1973. The mean length of these fish was 27.8 cm with a length range of 18-34 cm TL. The mean stomach fullness was 66%. The pooled sample of stomach contents contained 3040 *Caridina nilotica* and 30 *Macrobrachium niloticum*, indicating a mean stomach contents of over 150 prawns per fish. Studies on the Caridea (see Chapter 4) showed that *C. nilotica* occurred at a numerical areal density ten times that of *M. niloticum* during the sampling period. Thus selective feeding, with *C. nilotica* taken in preference to the larger *M. niloticum*, was exhibited by *L. longispinis* since all the specimens investigated were capable of eating fully grown individuals of both species of Caridea.

The diet of demersal *L. longispinis* of between 20 and 40 cm TL sampled during the present investigation in the Ferguson's Gulf area from a range of depth zones in the period May to August is shown in Table 11.31. The diet of these fish varied from nearly equal proportions of prawns and fish at depths of less than 30 m to a high proportion of prawns at depths of over 30 m. During May the bulk of the population of *L. longispinis* migrated into the 30-50 m depth zone which it occupied during the months June to August (see page 1310). From the observed diet (Table 11.31) fish occurring in water shallower than the 30 m contour preyed on both prawns and small pelagic fish of the scattering layer where it comes close to the bottom, but at greater depths *L. longispinis* caught in bottom gear fed primarily on prawns. These dwarf perch as a consequence were probably caught near or on the bottom, and not in midwater. During the months September to April the majority of *L. longispinis* migrated inshore to the 20-30 m depth zone, and specimens trawled from lake depths greater than 30 m were found to contain over 33% of fish in their diet (Table 11.31). This indicates that *L. longispinis* under these conditions was a pelagic feeder.

Seasonal variation in diet of demersal L. longispinis

The diet of all L. longispinis of 10 to 40 cm TL caught during routine bottom trawl surveys between June 1972 and November 1974 is presented on a seasonal basis in Table 11.32. The proportion of empty stomachs found in each 10 cm size class did not vary seasonally except in the 10-20 cm group which showed a high proportion of empty stomachs between April and September 1973. There was a variation in the diet of L. longispinis with time. This was most marked in the 10-20 cm size class, where the proportion of fish in the diet rose from almost zero in the months preceding January 1973, to 39% by May 1973 before a return to low levels in subsequent months. Similar trends from a largely prawn diet to an emphasis on the consumption of fish can also be recognised as occurring in the larger size classes. The relative change was not so dramatic since L. longispinis of over 20 cm TL habitually ingested fish at all times of the year. A degree of correlation exists between the seasonal fluctuation in the areal density of prawns (Figs. 4.17-4.18). With L. longispinis occurring over a wide depth range, the depth dependent dietary preferences will be superimposed upon the picture of seasonal variation, confusing the results. For this reason, a high degree of correlation between the density of prawns and quantity of prawns ingested cannot be expected, and monthly sample sizes are too small to allow further subdivision. However, the April 1973 minimum in prawn densities (Figs. 4.17-4.18) coincided with the observed maximum in the proportion of fish in the diet of L. longispinis, an indication that the density of prawns may have been too low for energy conservation and economic feeding.

FOOD OF PELAGIC Lates longispinis

Pelagic L. longispinis were caught in quantity during the period September to November 1975 when a lakewide survey with a Boris midwater trawl was conducted. Data from the examination of the diet of L. longispinis caught at this time are presented in 5 cm length classes in Table 11.33 together with the diet of L. longispinis for the same months in the years 1972-74. No difference in the proportion of empty stomachs or their relative fullness exists between L. longispinis from the two environments examined. No fish were found in the stomachs of L. longispinis in the 0-10 cm size class from either the demersal or pelagic samples. In all the larger size classes fish formed both a higher proportion of the total food present in the stomachs of pelagic L. longispinis and constituted a greater relative amount when compared with the diet of demersal L. longispinis. The relative increase in the quantity of fish ingested was highest in the 10-20 cm size class where the proportion rose from 4% to 65%. In the largest size class (40 cm +) the proportion of fish in the diet rose from 39% to 87% with the change from demersal to pelagic habit. Barbus spp., Bagrus bayad, Chrysichthys auratus and Haplochromis macconneli eaten by demersal L. longispinis were themselves demersal in habit, and pelagic species of prey, Alestes ferox and Hydrocynus forskalii, occurred in less than 5% of the total food. In the pelagically caught L. longispinis the principal prey species was Alestes minutus together with smaller numbers of A. ferox. Engraulicypris stellae probably comprised most of the unidentified fish remains which were darkly pigmented. Heavy pigmentation is a characteristic of E. stellae not present in the pelagic Alestes.

The diet of both demersal and pelagic L. longispinis is greatly different from Lates niloticus, the other species of Lates inhabiting the lake. The principal component of the diet of smaller L. longispinis is prawns, and the larger piscivorous L. longispinis take only Alestes spp. comprising the scattering layer, E. stellae, and small demersal fish. This is in contrast to L. niloticus which is piscivorous throughout the open water habitat, which it generally adopts at a size of 60 cm TL. Fish taken by L. niloticus are generally of a relatively larger size in relation to body length compared to L. longispinis even when they are of the same species.

Regional variation in the diet of pelagic Lates longispinis

Data from the study of the diet of all L. longispinis caught in the Boris midwater trawl from a lakewide survey conducted during the present investigations are presented on a regional basis in Table 11.34. The lake has been divided into four sectors, the extra sector gained by dividing the Central Sector into two along the junction between grid lines M and N (see Fig. 8.1). The proportion of empty stomachs is highest, at 61%, in the Northern Sector and zero in the south of the lake. This suggests periodic feeding behaviour with the adoption of a nocturnal feeding habit (see below) in the north of the lake, and a paucity of prey inducing continuous feeding in the south. No trend can be seen from the relative fullness of the stomachs of L. longispinis from various parts of the lake. Fish formed the major component of the diet in all sectors, with the highest proportion, 85%, occurring in the Southern Sector, and the lowest, 69%, occurring in the northern half of the Central Sector. Prawns formed the remainder of the diet in all areas, insects were not observed on any occasion. The major component of the identified fish was A. minutus except in the south, where A. ferox was more frequently identified. Unidentified fish probably include a high proportion of E. stellae for the reasons given above. The reltively high proportion of prawns found in the northern half of the Central Sector and in the Southern Sector is a reflection of the lack of scattering layer species in the areas investigated (see Fig. 8.79).

Hydrocynus forskalii formed a major part of the pelagic catch in the Boris midwater trawl and it is noticeable that the diet of this species is dissimilar to pelagic L. longispinis (Table 9.11). L. longispinis ingested a far larger quantity of prawns than did H. forskalii. Fish species taken by L. longispinis did not include very high proportions of A. ferox or E. stellae which recurred frequently in the diet of H. forskalii.

DIEL FEEDING BEHAVIOUR

The first of two 24 hour studies on the feeding behaviour of L. longispinis was conducted in April 1973 in 24 m of water off Longech Spit. The frame trawl was used to sample the water column at vertical intervals of 4 m, at five successive time periods. Data from each time period have been pooled, and are shown in Table 11.35. The vertical distribution of the fish caught is shown in Figure 8.35 and discussed on page 1311 . The catch was of mostly small L. longispinis with an average length of 11 cm, although the overall size range caught was 2-31 cm TL. Data (Table 11.35) show an increase in the proportion of empty stomachs in the sampled population, to a maximum of 47% by 02.00 hrs. By the next sample at 06.00 hrs, all the stomachs contained food, indicating that the majority of L. longispinis were not feeding between the hours of sunset and 02.00 hrs, but that feeding activity started between the hours of 02.00 and dawn. Mean relative fullness of the stomachs which was highest in the afternoon sample fell to a minimum of

23% by midnight but increased to 40% by the dawn. During the hours of daylight prawns formed between 98% and 99% of the contents of the stomachs, which were up to 63% full. The relative proportion of prawns in the diet fell to 76% in the night sample. During the hours of darkness fish, particularly E. stellae, formed up to 23% of the diet, and the potential amount of fish ingested increased from zero in the evening sample to 7% in the dawn sample. Insects were eaten only infrequently.

The second 24 hour study on the food of L. longispinis was conducted during October 1975 at the same locality with the use of the Boris midwater trawl to sample the full water column. In a series of seven time periods L. longispinis of the size range 7-33 cm were collected, and details of diet are summarised in Table 11.36. The proportion of empty stomachs reached a peak of 36% at 19.05 hrs, fell to zero by 23.12 hrs, and rose to a maximum of 55% by 10.39 hrs the next day. Maximum relative fullness was not reached until 03.05 hrs; identical minima were observed at 19.05 hrs and 10.39 hrs. These figures are indicative of continuous feeding by the population from the hours of midnight to dawn, with fish feeding intermittently thereafter.

The larger fish observed in the October sample appeared to feed earlier than the smaller fish observed in the April survey. The highest proportion of prawns in the diet occurred during the hours of daylight, with a maximum of 70% recorded at 10.39 hrs, and a minimum of 26% at 23.12 hrs. The highest relative amount of prawns (16%) in the stomachs occurred at dawn; the minimum occurred at 19.05 hrs, 1½ hours after sunset. The proportion of fish in the diet rose to a maximum of 74% at 03.05 hrs, the relative fullness due to fish rose to a peak of 23% at the same time. Both the proportions of fish and the quantity in the stomach fell to a minimum at 10.39 hrs. Fish in the diet were primarily A. minutus and E. stellae.

The diel feeding studies of L. longispinis show that the principal non-feeding period was between sunset and midnight during the course of vertical migration. The larger fish, which would have reached the optimum light level first, started feeding by midnight, and all size classes were feeding by 03.00 hrs. All size classes fed until dawn, when a proportion of the larger size classes became quiescent and sank to the bottom, while smaller size classes continued to feed during the descent to the bottom. Daytime feeding was largely devoted to prawns and night time feeding to the dispersed scattering layer.

RELATIVE SIZE OF PREY

The results of observations on the size of whole identifiable prey species ingested by L. longispinis are shown in Figure 11.17, where size of prey is plotted against size of predator. The total lengths of Caridea were converted from recorded values of carapace length by means of the values given in Table 4.3. It is apparent that the smallest size classes ingested prey at the greatest relative size of fish until the predator started to show a change to a piscivorous diet. Maximum relative size of prey did not go beyond 40% in any species, considerably less than the mean value of 45% observed in L. niloticus.

ECTOPARASITES

Although both argulids and lernaeids were noted on *Lates niloticus* in Lake Turkana, only one species of ectoparasites, the lernaeid *Opistholernaea longa* (Harding), was recorded on *Lates longispinis*. However, argulid infestations in *L. niloticus* was restricted to fish living in shallow water and, as shown above, *L. longispinis* was principally offshore in distribution.

O. longa was observed on *L. longispinis* ranging from 6 to 58 cm TL, the parasites firmly anchored in the flesh of the host, mainly on the ventral surface but also on the caudal peduncle and at the base of the dorsal fin. Generally only a few parasites were attached to a single host, but rates of infestation were observed to vary with both the depth of the sample and the time of the year. From the examination of the frequency with which parasitised *L. longispinis* appeared in trawl catches, it became apparent that such fish were aggregated and not randomly distributed through the population. Thus with increasing depth of water the frequency with which lernaeids occurred in catches of *L. longispinis* rose steadily from zero in water of 0-10 m deep to 28% in water of 30-40 m, to fall to 17% in water of over 40 m deep. However, taking the *L. longispinis* population as a whole, the percentage of infested fish reached a maximum in the 30-40 m depth zone, but decreased at greater depths (see below).

Seasonal variation occurred in both the frequency with which *O. longa* appeared in trawl hauls and in the proportion of *L. longispinis* parasitised in such hauls. The general trend was for parasites to be absent from *L. longispinis* in the post-flood season (March-June) but for both the frequency of occurrence of *O. longa* in hauls and the proportion of *L. longispinis* parasitised to rise to a maximum in the post-flood season (November-February). In the post-flood season in the Northern Sector *O. longa* appeared on *L. longispinis* in 96% of the hauls and at those times at which *O. longa* occurred, 48% of the fish were parasitised, the respective rates being 80% and 12% in the Central Sector. It is apparent that a close correlation existed between the rate of parasitisation and the incursion of flood water from the River Omo. The two exceptions to the generalised picture of the distribution of *O. longa* given above reinforce this idea. *L. longispinis* with *O. longa* attached occurred at two stations during the post-flood period, one in 40 m of water near the Kerio-Turkwell deltas, and the other in over 60 m of water off the west coast in the Southern Sector. On both occasions, over 90% of the *L. longispinis* caught were parasitised. The distribution of these *L. longispinis* strongly suggests that parasitisation was linked with the flooding of the Kerio and Turkwell Rivers which flow strongly into the lake at that time of year.

The aggregation of *L. longispinis* parasitised by *O. longa* complicated quantitative estimation of parasitisation rates. An estimate of the mean rate of parasitisation of the population was obtained by summing the frequency with which parasitised *L. longispinis* appeared in all quantitative bottom trawl hauls, expressed as number caught per standard haul. This number was then expressed as a percentage of the total number of *L. longispinis* caught. The analysis was done on a regional basis, both by depth zone (Table 11.37) and season (Table 11.38). In Table 11.37 the single sample at 40+ m in the Northern Sector cannot be significant due to the aggregation of infested *L. longispinis*. The remaining observations do, however, give an idea of the mean rates of parasitisation within the population as a whole.

Numbers of parasites per fish tended to increase with depth of water, a maximum of 64.0 *O. longa* on one *L. longispinis* was recorded in 30-40 m of water, and 60 lernaeids were counted on another fish in 40 m + of water. Seasonal variation in parasitisation (Table 11.38) was most marked in the Northern and Central Sectors of the lake. The parasites recorded in the post-flood season all occurred south of the Turkwell River (see above) and in the rest of the lake no parasites were observed on *L. longispinis*. During the flood season the proportion of *L. longispinis* infested with lernaeids rose to a peak, reaching a rate of 9.1% in the Northern Sector, and during this period mean numbers of *O. longa* per fish was highest in the Central Sector where an average of 5.9 lernaeids were observed on infested *L. longispinis*. In the post-flood season the proportion of the population parasitised by *O. longa* fell to as low as 2.4% in the Central Sector, but the numbers of parasites on infested fish rose to a maximum of 9.3, also in the Central Sector. This was probably due to the post-spawning mortality of larger *L. longispinis* (see above) reducing the proportion of infested stock, while parasitised fish continued to be hosts to increasing numbers of lernaeids as time progressed.

SUMMARY

The biology of *Lates longispinis*, an unexploited dwarf Nile perch, endemic to Lake Turkana (Kenya), was studied during the period June 1972-November 1975. Specimens collected range in length from 2-64 cm total length (TL), smaller *Lates* spp. post-larvae and juveniles could not be identified as either *L. longispinis* or *L. niloticus*.

Material was collected in bottom, midwater and frame trawls, a metre townet, and gillnets. Occasional individuals were caught in a beach seine.

Recruitment of younger *L. longispinis* into the trawling areas was incomplete, probably due to a tendency for specimens of less than 4 cm to inhabit the marginal areas.

Lates longispinis was widely distributed throughout the lake, primarily at and below the depth zone where the scattering layer impinged on the bottom. The species was uncommon inshore from the limit of the scattering layer and was totally pelagic in water of over 50 m in depth. Lakewide mean catch per unit effort in bottom trawl hauls averaged 34.1 Kg/hr. Peak catches occurred in the northern half of the west side of the lake between the 20 to 30 m contours, where *L. longispinis* comprised ca 35% of the total catch by weight in bottom trawl hauls. Relative proportions of length classes tended to be constant in bottom trawl catches from all depth zones. Fish of over 45 cm TL were demersal, with all other size classes dispersing through the pelagic layers.

During the hours of daylight *L. longispinis* in inshore regions ranged from the depth of the scattering layer to the bottom. Diel vertical migration occurred with *L. longispinis* rising in the water column at night, maintaining a minimum depth greater than the species comprising the scattering layer (*Alestes minutus*, *A. ferox*). Seasonal inshore migration occurred, the mean diurnal depth of the population varied with the water transparency and in the Ferguson's Gulf area ranged from 10 m during the flood season to 40 m prior to the flood season.

Bottom set gillnets yielded peak catches of *L. longispinis*, principally in areas extending a short distance offshore from the point where the scattering layer impinged on the bottom. Mean catch per unit effort in this locality was 15 Kg/100 metres of 3" net, with *L. longispinis* comprising 18% of the catch.

Regular annual recruitment enabled growth rates to be estimated by Petersen's method. No sexual differences in growth rate were found. The growth parameters on a von Bertalanffy model were: $L_\infty = 70.4$, $K = 0.31$, $t_o = 0.19$ from a birth date in December. Mortality in the larger size classes was estimated to be $Z = 1.11$. No sexual differences occurred in the length-weight relationship for *L. longispinis* and a mean of $w\ (gm) = 0.014\ TL\ (cm)^{2.88}$ was determined for all recorded specimens. Mean condition $(k = \frac{100w}{l^3})$ decreased from a maximum of 1.27 in the smallest size class to 0.92 in the largest adults, with no apparent sexual differences. Condition showed a seasonal peak in April and a minimum in June-September in both juveniles and sexually mature adults.

Females reached 50% maturity at ca 30 cm TL corresponding to an age of two years, and had spawned at least once by an age of three years. Males reached 50% maturity at ca 28 cm TL. Peak spawning during the period January to March with a reduced rate of spawning in all other months. Spawning grounds were identified on the west coast in the northern half of the lake, between the 10-30 m contours. Females tended to predominate except in the 20-30 m depth zone where there was a surplus of males. Seasonal variation in sex ratio showed a higher mortality in males during the post-spawning period.

The principal items eaten by *L. longispinis* were the prawns *Caridina nilotica* and *Macrobrachium niloticum* and the fish *Alestes minutus*, *A. ferox* and *Engraulicypris stellae*. *Lates longispinis* of less than 35 cm TL which fed largely on prawns and larger fish were principally piscivorous. Demersal *L. longispinis* tended to eat more prawns than pelagic *L. longispinis* and those fish species eaten were mainly demersal. Studies of seasonal dietary changes showed a peak in the fish content coinciding with a minimum in the population density of prawns. Diel feeding studies showed that *L. longispinis* generally did not feed between sunset and midnight and that all specimens were feeding actively by 03.00 hrs. The proportion of fish in the diet rose during the hours of darkness. The maximum relative size of prey was 40%, and the average was generally much lower.

L. longispinis was parasitised with *Opistholernaea longa*. Rates of infestation increased with depth and reached a seasonal peak during the flood season.

REFERENCES

COULTER, G W (1965). Lake Tanganyika research report. *Fish. Res. Bull. Zambia*, *2*: 4-8

COULTER, G W (1976). The biology of *Lates* spp (Nile perch) in Lake Tankanyika and the status of the pelagic fishery for *Lates* species and *Luciolates stappersii* (Blgr) *J. Fish. Biol.* *9* : 235-259

CUSHING, D H (1951). The vertical migration of planktonic crustacea. *Biol. Rev.* *26* : 158-192

GEE, J M (1965). Nile perch investigations. *Ann. Rep. E. Afr. freshw. Fish. Res. Org.* *1964* : 13-17

GREENWOOD, P H (1976). A review of the family Centropomidae (Pisces, Perciformes). *Bull. Br. Mus. nat. Hist.* (Zool). *29* : 4-81

HOPSON, A J (1972). A Study of the Nile Perch (*Lates niloticus* (L), Pisces: Centropomidae) in Lake Chad. *Overseas Res. Publ.* *19* : 93 pp. HMSO London

HYNES, H B N (1950). The food of the freshwater sticklebacks (*Gasterosteus aculeatus* and *Pygoesteus pungitius*) with a review of the methods used in studies of the food of fishes. *J. Anim. Ecol.* *19* : 35-58

LONGHURST, A R (1976). Vertical migration. In *The ecology of the sea*, ed. Cushing, D H and Walsh, J J, pp 116-137. Blackwell Scientific Publications. Alden Press, Oxford.

PETERSEN, C G J (1892). Fisensbiologiske forhold i Holboek Fjord, 1890-91. *Beretning fra de Danske Biologiske Station for 1890 (91.* *1* : 121-183.

RICKER, W E (1973). Linear regressions in fisheries research. *J. Fish Res. Board Can.* *30* : 409-453.

SSENTONGO, G W and LARKIN, P A (1973). Some simple methods of estimating mortality rates of exploited fish populations. *J. Fish Res. Board Can.*, *30* : 695-698.

WORTHINGTON, E B (1932). Scientific results of the Cambridge Expedition to the East African Lakes 1930-1. 2. Fishes other than Cichlidae. *J. Linn. Soc. (Sool).* *38*: 351-362.

WORTHINGTON, E B and RICARDO, C K (1936). Scientific results of the Cambridge Expedition to the East African Lakes, 1930-1. 15. The fish of Lake Rudolf and Lake Baringo. *J.Linn. Soc. (Zool).* *39* : 353-389.

THE BIOLOGY OF THE LARGER CICHLID FISH OF LAKE TURKANA

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INTRODUCTION

A total of seven species of cichlid fish have been recorded from Lake Turkana but only three, *Sarotherodon niloticus*, *Sarotherodon galilaeus* and *Tilapia zillii* grow large enough for them to be of actual or potential commercial importance. These three species form the basis of the present account.

Earlier observations on the biology of the larger cichlids of Lake Turkana are few. Taxonomic material collected by the 1930-31 Cambridge University Expedition was examined by TREWAVAS (1932) and biological data obtained concurrently were analysed by WORTHINGTON and RICARDO (1936). They found that *S. niloticus* was the predominant species in all catches of large cichlids throughout the area investigated including Ferguson's Gulf, Central Island Moite. This species was also predominant in the indigenous plunge basket fishery noted in the Ferguson's Gulf area. *Tilapia vulcani* Trewavas 1932, collected by the Expedition from Crater Lake A, Central Island, is now regarded as a synonym of *S. niloticus* (TREWAVAS, 1973).

LOWE (1958) includes data collected from Lake Turkana in January 1953 in a review of the biology of *S. niloticus* in waters throughout East Africa. She provides valuable information on various aspects of the biology of the Lake Turkana population including size at maturity, length/weight relationship, dwarfing in lagoon populations and their unusual ability to assimilate the blue-green algae *Spirulina* and *Anabaenopsis*.

During the initial period of commercial exploitation in the 1950's a beach seine fishery which developed in the Ferguson's Gulf area was based chiefly on *S. niloticus*. MANN (1964) notes that in 1963 two small beach seines were in use. The fishery persisted in a localised area on beaches at the northern extremity of Longech Spit where *S.*

niloticus still dominates the catch.

With the introduction of gillnets in the 1960's, the relative importance of S. niloticus in commercial catches declined considerably, except in certain areas such as Kerio Bay and the east shore between Allia Bay and Moite (see Chapter 6). However, since 1974, Ferguson's Gulf has become by far the most important fishing region in the lake due to a phenomenal increase in the population densities of S. niloticus, which has dominated commercial catches since 1975 (Table 11.39).

Surveys carried out during the present project have shown that S. galilaeus and T. zillii, which have more specialised habitat preferences than S. niloticus, are also locally important to Lake Turkana under the appropriate environmental conditions. The larger cichlids as a group are thus clearly a most valuable resource, particularly in view of the excellent quality of their flesh and the high market price they command.

The present study deals with the distribution, growth and breeding of the three species. Feeding is considered in a separate report (see page 1357 below).

MATERIALS AND METHODS

The results are based chiefly on fish from Ferguson's Gulf caught with graded fleets of gillnets ranging from 3 to 6 inches stretched mesh. Supplementary material was obtained from beach seine samples, both from routine monthly hauls at Met Bay, Longech, and from irregular hauls made at sampling stations in localities scattered throughout the lake, particularly during the Shore Survey (see Chapter 7, page 563). Owing to their preference for shallow marginal areas of the lake, very few Sarotherodon or Tilapia were recorded in trawl catches. Specimens were, however, caught regularly by rod and line from the shore, particularly on rocky coastlines. The fry of large cichlids occurred commonly, at times abundantly, in foot seine samples on beaches of mud, sand, gravel or stones, throughout the lake.

The total length of fish was used as an index of size throughout the present studies. Details of techniques used in particular aspects of the study are described in the relevant sections below. Terms used in the present work for different stages of the larger cichlids require definition. The term 'fry' applies to young fish from the time when they cease to be brooded, up to a length of 5 cm TL. 'Juvenile' is a loose term covering a size range from 5 cm up to a length of ca 15 cm. 'Adolescent' and 'adult' include respectively immature and mature fish of larger size groups.

DISTRIBUTION

The three species under considersation were essentially shallow water forms restricted to the inshore waters of the lake. Bottom trawl data (Table 11.40) clearly illustrate this trend with catches of S. niloticus declining sharply with increasing depth, and none recorded in 124 hauls from offshore areas beyond the 30 metre contour. A high proportion of fish included in the results for the 0-5 cm depth zone were caught in Allia and El Molo Bays.

Boris midwater trawl data (see Chapter 8, page 600) show that S. niloticus at times occurred further offshore. Three out of 80 hauls made during the midwater trawl survey included single specimens of S. niloticus ranging from 4 to 25 cm TL. The stations, at depths of 21, 31 and 41 m lay adjacent to one another on the western side of the Northern Sector of the lake (see Fig. 8.29) suggesting that at the time of the survey in October 1975 small numbers of the species were scattered throughout the offshore water in that particular area. The presence of these fish far from the usual inshore habitat suggests that a dispersl movement may have been under way.

HABITAT PREFERENCES

Sarotherodon niloticus

This species is primarily a phytoplankton feeder and is especially dominant in regions of dense algal stocks such as exist in Ferguson's Gulf. Not only is this the most numerous large cichlid, it is also the most widespread, inhabiting shorelines around the whole lake. Phytoplankton densities in the main lake are insufficiently high to support S. niloticus directly, but the fish also feeds by grazing from muddy surfaces, rocks, and on concentrations of loosened 'aufwuchs' in the southwest of the lake.

Sarotherodon galilaeus

This species prefers regions with a substrate of silty mud, and grazes a mixture of phytoplankton and epibenthic algae. The process involves filtering mud/water interfaces and loose substrates. It is therefore restricted to sheltered bays, mainly on the eastern lake shore. The most important populations of S. galilaeus on the western side of the lake were observed on the sheltered shore between Kerio and Meriar.

Beach seine data may not provide a true reflection of the population densities of this species, however, since S. galilaeus often jumped over the encircling net when other species were caught.

Tilapia zillii

This species had the most clearly defined habitat preferences. It grazed rocky shores, more actively than S. niloticus, using the teeth to scrape epilithic algae. It also ingested gravel and sand particles, bearing algal or bacterial floras. The distribution of T. zillii was restricted mainly to rocky shores, although small populations were recorded in the vicinity of extensive Potamogeton beds where epiphytic growths provided a suitable food source.

Each of the three species showed clearly defined preferences for nesting, breeding and nursery grounds.

The most productive cichlid fishery in the lake is currently situated in Ferguson's Gulf and in the account which follows, this area is considered apart from the remainder of the lake.

ADULT AND JUVENILE DISTRIBUTION

Ferguson's Gulf

The area of this sheltered region is ca 30 km^2, but the huge commercial catches of recent years (see Chapter 6) have been made within the south-eastern third - a direct reflection of the late-juvenile/adult distribution. In turn, this distribution is related to two main factors:

(i) Food availability

From Chapter 2, it is clear that during 1975, when the fishery was developing, the densest concentrations of healthy algae were situated in the central and south-eastern areas of the gulf.

(ii) Nesting site availability

In earlier years, nest sites were usually clearly demarcated by stick markers placed in them by fishermen as an aid to plunge-basket fishing. Sarotherodon niloticus nests were most common along the eastern gulf margins. The substrate preferred was firm sand, suitable for the construction of discrete nests free from the disturbance of wind-driven water movement.

Sarotherodon galilaeus was most frequently recorded midway along the western shore of Longech Spit where, again, food and nesting site suitability were optimal. The substrate here was less firm than to the south, and provided a source of epibenthic/settled planktonic algal and bacterial material.

Table 11.41 illustrates the frequencies of the three species in beach seine catches within the gulf. The rarity of T. zillii was due to the lack of substrates suitable for breeding or feeding.

The main lake

Information on the distribution of these species outside Ferguson's Gulf is available for over 200 stations sampled with beach seine nets during the present study (Table 11.42). Most hauls were part of a shore survey around the more accessible parts of the lake (see Chapter 7, Fig. 7.15 and Table 7.1). The paucity of information from Sirima Head to Loelia indicated by Figure 7.15 is due to the difficulty of sampling steep, rocky, high energy shores (see Fig. 1.24-25).

The western shore north of Kataboi was mostly devoid of Sarotherodon and Tilapia as a result of scouring by wave and current action. A similar dearth of cichlids was noted on exposed sandy and gravelly shores from Longech to Eliye and from Sandy Bay to Porr Point.

It might be predicted that exposed and precipitous coastlines in the south basin would also lack cichlids, but this was not the case. The depth of water close inshore on these rocky shores provided protection from turbulence while the wave-energy itself created a build-up of loosened 'aufwuchs' which, together with attached epilithic populations, were grazed by S. niloticus and T. zillii. Such shorelines were sampled only by rod and line, although in the relatively transparent water it was possible to make observations directly from the land.

In exposed sandy areas the prevailing south-easterly winds generated currents which created spits and lagoons. The shelter so formed provided conditions suitable for dense algal growth and for high sedimentation rates. The shallow waters in these areas usually excluded adult fish but conditions were ideal for juvenile populations and S. niloticus was particularly common under such conditions.

FRY DISTRIBUTION

The occurrence of cichlid fry in an area indicated the presence of nursery grounds and the close proximity of spawning grounds since it is unlikely that the early stages migrated appreciable distances. The fry of Sarotherodon niloticus, and probably those of the other species too, preferred shallow marginal areas of the lake at depths of between 5 and 30 cm. The young fish were tolerant of high water temperatures which regularly exceeded 35° C. At night they tended to move into deeper water or into the shelter of macrophytes.

Ferguson's Gulf

The occurrence of fry in Ferguson's Gulf

As mentioned previously, both S. niloticus and S. galilaeus bred chiefly along the south-eastern margin of the gulf where the substrate was sandy and conditions sheltered. Breeding was restricted on the western shore of the gulf by lack of suitable substrate and by the strong turbulence resulting from the prevailing south-easterly winds. No definite breeding sites for T. zillii were located within the gulf, but as with the Sarotherodon spp., they probably preferred conditions on the east shore where a combination of firm sand and shelter was found.

Sarotherodon niloticus was by far the commonest species of cichlid in collections of fry from Ferguson's Gulf where this species also dominated the commercial fishery. The pattern of distribution of fry is shown in Table 11.43 and Figure 11.19. Shoals of fry were recorded on shorelines throughout the gulf but marked local differences were observed. The slope of the western shore of the gulf was very gradual compared with the eastern shore and provided much larger areas of water between 5 and 30 cm deep for fry to inhabit (see Chapter 1). As the lake level changed seasonally, the margin shifted considerably, resulting in appreciable changes in the area of the gulf as a whole. The expanse of shallow water of 5-30 cm showed little seasonal variation since the slope of the shore was fairly constant. The amount of vegetation cover on the western shore, however, varied considerably, both seasonally and interannually. Since the macrophytic vegetation provided both shelter and attachment for epiphytic food, the effect of such changes on populations of young cichlids has been profound, as will be discussed in detail below.

The importance of the western shore of the gulf as a nursery area suggests that the population originates from the main spawning areas on the east shore and that there was a constant movement of fry along the southern shore from one area to the other. This westerly movement may have been assisted by currents since it followed the general circulation pattern of the gulf (see Chapter 1, Fig. 1).

With the establishment of a large fishing settlement on the east shore of the gulf during 1974-75, large concentrations of fry were noted close inshore in this area feeding on the gut contents of eviscerated fish which had been deposited in the lake margin. This probably indicates a significant increase in fry populations to the east of the gulf.

The open lake

The occurence of fry in the main lake is illustrated by distribution charts (Figs. 7.12-14, see Chapter 7, page 561) which are based on samples made with the fine foot seine during the Shore Survey. Sarotherodon niloticus fry were by far the most abundant of the three species occurring ubiquitously in nearly all areas of the lake. There was however a tendency for densities of this species to be higher in sheltered bays such as the entrance to Ferguson's Gulf, Meriar, El Molo and Allia Bays (Fig. 7.12). The charts indicate comparatively little difference between more open shores to the east and west of the lake, particularly in more northerly areas. Although the west coast north of Longech was open and exposed to wave action, numerous small sand spits were continually forming and reforming with the result that shelter for small fish was plentiful. South of Longech, the exposed coastline tended to be less broken and S. niloticus fry were generally rare. No collections were possible with the foot seine on precipitous shorelines in the south, but although adult S. niloticus and T. zillii were often observed at close quarters from the land, cichlid fry were not noted.

Sarotherodon galilaeus and Tilapia zillii fry were uncommon in the fine foot seine samples (Figs. 7.13-14). In each case the pattern of distribution reflected the habitat of adult fish with S. galilaeus tending to occur on soft substrates on both east and west shores, and T. zillii fry restricted in the foot seine samples to areas where harder substrates predominated, on the east shore between Kakoi in the north and Lotarr in the extreme south. Foot seine samples from South Island contained fry of both S. niloticus and T. zillii, indicating that although suitable substrates for spawning were limited to two open beaches of volcanic ash, breeding was successful. Tilapia zillii fry probably also occurred in the south west where stretches of cliff and boulder were broken by occasional beaches of coarse sand and shingle, as at Mugurr and Kapoi.

Although the Omo delta was not sampled during the shore survey, observations from aircraft suggest that much of the shoreline to the east of the Dier subdelta provided breeding sites for Sarotherodon spp. The recent connection of Lake Fajda to the main lake (see Chapter 1, Fig. 1.9) created a large, shallow, sheltered bay which is undoubtedly an important breeding area for large cichlids. During the season of low lake levels numerous nesting craters of Sarotherodon could be seen on the dried up margins of the gulf formed by Lake Fajda. The cichlids of this area are likely to provide an important resource, and juveniles probably disperse southwards to colonise the shores of the open lake.

DISPERSAL STAGES OF Sarotherodon niloticus

Figure 11.20 shows the result of regular sampling with the 50 metre long 19 mm mesh beach seine on the east shore of Ferguson's Gulf. It is evident that there was a marked tendency for S. niloticus of specific size groups to occur in the catches. Fish of up to 10 cm FL predominated, and larger individuals of over 20 cm FL also appeared regularly. Juvenile and adolescent fish of between 10 and 20 cm were, however, infrequently recorded and the results indicate that at a length of ca 10 cm, the young fish moved out of the 100 m wide inshore zone sampled by the net. It seems likely that this movement represents a dispersal phase by means of which the species is able to colonise areas which have recently become habitable in a rapidly changing environment. Gillnet catches suggested that the 10-20 cm fish were not present in the main feeding grounds where adult S. niloticus concentrated in the south-eastern sector of the gulf and it seems likely that they tended to inhabit the open waters of the central and northern gulf. Movement in and out of Ferguson's Gulf undoubtedly occurred, but it is difficult to estimate what proportion of the juvenile population was involved. However, since the explosive increase of S. niloticus populations in Ferguson's Gulf during 1974-75 is considered to be due to high survival of juveniles within the gulf itself, there is a likelihood that with the prevalent abundance of algal food, a high proportion remained in the area.

Although S. niloticus of 10-20 cm were uncommon in beach seine catches in Ferguson's Gulf, they are well represented in samples from other areas of the lake, probably due to the presence of deeper water closer inshore.

The Ferguson's Gulf data indicate that adolescent fish of ca 20 cm and above moved closer inshore but did not enter the breeding areas until the onset of sexual maturity at a length of ca 28 cm TL.

GROWTH

AGE DETERMINATION

Seasonal growth checks on the scales, opercular bones and other hard parts of African freshwater fish are caused by a variety of factors, the chief of which are: (i) slowing down of growth during a 'winter' period of lowered water temperatures, (ii) breeding behaviour of a strongly seasonal nature, and (iii) seasonal food shortages. The large cichlids of Lake Turkana which form the basis of the present investigations were subject to an exceptionally stable temperature regime, spawned cyclically throughout the year, and suffered no seasonal shortage of food. Under such circumstances, regular growth checks were not formed, and age determination by the analysis of seasonal rings proved to be impossible. TAUBERT and COBLE (1977) found that in West African lagoons, Sarotherodon mossambicus laid down daily rings in the otoliths. Since the dominant environmental and feeding activity rhythms were strictly diurnal, both in the S. mossambicus population and in the cichlids of Lake Turkana, such rings may be more widespread than so far reported.

No observations were made on the otoliths of cichlids in Lake Turkana but counts of scale circuli were made for S. niloticus. Scales were first formed at a total length of 1.1 cm and circulus formation commenced immediately (see also FISCHELSON, 1966; KRUPKA, 1974). It was found that the number of circuli was linearly related to length up to a size of ca 12 cm (Fig. 11.21). The physiology and timing of circulus formation is at present unknown for the Lake Turkana population, and further investigations should be undertaken on experimental populations to determine if any direct relationship between age and the number of circuli exists. Concomitant observations on otolith rings formation should also be made.

LENGTH FREQUENCY ANALYSIS

Growth and age may be investigated by the regular sampling of a population in which age classes may be recognised as characteristic modes on length frequency histograms. In this way, the progression of age cohorts as they increase in size may be followed in successive samples, and estimates of growth rates thus achieved (PETERSEN, 1892). This method has been used for S. niloticus in Lake George by GWAHABA (1978), but the technique is usually limited in application to waters where spawning is a seasonal event. Populations of S. niloticus in Lake Turkana continue to spawn throughout the year. A further obstacle to successful length frequency analysis during the present studies was the tendency for the population to segregate into a number of discrete size groups, each favouring specific habitats. Thus individuals of a particular size range favoured specific habitats, and the size structure of successive samples from a particular locality remained comparatively unchanged. The problem is illustrated in Figure 11.20 which shows length frequencies of regular beach seine samples obtained from a site on the east shore of Ferguson's Gulf over a period of 9 months. There was no obvious change in mean cohort size, and groups of 5-10 cm and 19-25 cm were recorded in 7 out of 11 samples. The results indicate that a succession of similar-sized fish occupied the sampling area throughout the period, suggesting that a regular pattern of local migrations was followed during the course of growth, with each size group tending to occupy a particular type of habitat.

Breeding data (see below) show that mortality rates of S. niloticus fry varied considerably over the course of the year as a result of changing environment conditions. The survival rate of fry rose to a peak in the Ferguson's Gulf area during the flood season between August and November each year, when grassy areas on the lake margin became inundated. The effect of such seasonal changes was to create a dominant size group each year. This in turn resulted in seasonal fluctuations in the commercial fishery, with catches in Ferguson's Gulf increasing considerably during March and April each year as the stocks were replenished by the influx of the dominant size cohort of late 0-group fish into the fishing grounds.

During 1975, the mean mesh size of commercial gillnets used in the gulf lay between 3.5 and 4 inches stretched mesh. The mean selection length of such nets for S. niloticus lies between 23.0 and 24.5 cm (Fig. 11.22 and Table 11.44). Commercial catches of S. niloticus in the gulf during 1975 remained consistently high up to July. It is believed that the exploited population had been spawned during and immediately before the 1974 flood season, which indicates that a mean growth rate of approximately 2.3 cm/month was maintained over the first 10 months of life.

Maximum lake levels during 1975 were recorded in September and October, and optimum conditions for fry survival were again in evidence. During 1976, the mean mesh-size of gillnets employed in the commercial fishery had risen to between 4.5 and 5 inches stretched mesh, and S. niloticus of between 28 and 30 cm were selected most strongly. Maximum commercial catches in the gulf in 1976 were not reached until August of that year. It is considered that this delay was due to the increased time required for the 1975 cohort to grow to the size selected by the nets. It is estimated that the mean growth rate for the 1975 fish was approximately 2.5 cm/month. Subsequently, catches in 5 inch nets declined, and during September 1976 higher yields were obtained with 6 inch nets. Towards the end of October 1976, catches also fell in the 6 inch nets but high levels were maintained by the introduction of 7 inch nets. The larger nets were fished together with the smaller nets of 4-5 inch mesh throughout the last four months of 1976 but the larger mesh sizes invariably caught more fish. Catches in 5 inch nets increased once more in the new year, and by mid-January 1977 the larger mesh sizes were discontinued.

Commercial catches thus revealed an annual pattern of recruitment with a dominant length cohort of S. niloticus arising as a result of seasonally high survival rates during the flood season and subsequently growing at a rate of ca 2.3-2.5 cm/month to reach a commercial size of ca 26-28 cm by the flood season of the following year.

TAGGING

Under the direction of Dr J Rinne, then of E.A.F.F.R.O, Kisumu, a tagging programme was initiated in Ferguson's Gulf with the object of estimating growth rates from increments observed in recaptured fish after a known time interval. During October 1974, over 2000 S. niloticus of 12 cm to 28 cm were tagged using the method described by RINNE (1975). Unfortunately no recoveries were reported among the many fish caught in commercial nets during the succeeding 24 months.

DISCUSSION

The extrapolation of growth rates for experimental populations of Sarotherodon and Tilapia to natural populations is open to criticism on several grounds. Cichlid fish stunt readily under conditions of limited food availability, in small ponds or as a result of overcrowding (see for example FRYER and ILES, 1972). Stressed fish have been noted to produce low quantities of gastric acid which reduces their efficiency at assimilating algal material (MORIARTY, 1973; HARBOTT, 1975). Stress may result from frequent handling, changes in captive environment, or by restriction of movement due to high stocking densities.

Observations carried out on stocks in large, well-planned experimental ponds and enclosures have yielded many consistent and repeatable results with species of Sarotherodon and Tilapia, which are relevant to the present investigations. Thus in a review of recent work on Lake George, LOWE-McCONNELL (1975) reports that S. niloticus in 'Netlon' cages grew from 3.0 to 19.5 cm TL in 7.5 months. This represents an average rate of 2.2 cm/month, which is similar to the tentative estimate of ca 2.4 cm/month for the Ferguson's Gulf population. The similarity in the ingestion rates for algal food recorded for S. niloticus in Lake George and for Lake Turkana population (see page 1365) would itself indicate close parallels between the two populations.

Elsewhere, RINNE (1975) working on S. niloticus in 0.05 ha x 100 cm deep ponds at Kisumu recorded growth rates of up to 4.3 cm/month for fish of 8-17 cm, and rates of 1.9 cm/month for fish over 18 cm TL. He obtained values of 2.5 cm/month and 2.2 cm/month for cage populations of 5-8 cm and 8-10 cm respectively. None of these fish was tagged or fed artificially.

The estimates of growth rate in the Ferguson's Gulf population of S. niloticus during their first year thus lie within the recorded limits obtained during experimental work in other areas of East Africa.

LENGTH-WEIGHT RELATIONSHIP

The relationship between length (l) and weight (w) in fish is usually represented by the expression:

$$w = a\ l^b \qquad (1)$$

hence:

$$\log w = l \log b + \log a \qquad (2)$$

During the present studies length-weight data were collected for each of the three species of large cichlids, and values of the power b and coefficient a were obtained by fitting a linear regression to equation (2) above. Length was recorded to the nearest 0.1 cm, and weight in grammes.

Length-weight relationship of Sarotherodon niloticus

Measurements and weights were obtained from beach seine and gillnet catches at Ferguson's Gulf, Allia Bay, Moite and Sandy Bay. The data were analysed on the basis of sex, size and locality (Table 11.45). By combining results from all sources, the following relationship illustrated in Figure 11.23 was obtained for the Lake Turkana population of S. niloticus:

$$w = 0.0234\ l^{2.99}$$

Measurements of S. niloticus caught in Ferguson's Gulf during January 1953 and quoted by LOWE-McCONNELL (1958) have been used to calculate the following expression:

$$w = 0.0123\ l^{3.16}$$

A regression line for these earlier results plotted logarithmically is shown in Figure 11.24. Identical results for the Lake George population of S. niloticus were obtained by MORIARTY (1973).

The relationship between length and weight for the population of S. niloticus in Crater Lake A, Central Island (Fig. 11.25) caught by rod and line during May 1975 is described by the equation:

$$w = 0.0182\ l^{2.93}$$

These observations indicate that the Crater Lake A fish tended to be in poorer condition than populations in the main lake. Ecological implications are discussed below.

Length-weight relationship in Sarotherodon galilaeus

Data for S. galilaeus were collected from various localities in Lake Turkana during the present investigations (Fig. 11.26) and the following relationship between length and weight was calculated:

$$w = 0.0234\ l^{3.01}$$

A value of $r^2 = 0.996$ was obtained for the regression of log w on log l.

Insufficient numbers of *Tilapia zillii* were weighed for a satisfactory analysis to be made.

BREEDING

SEXUAL STAGES

Maturity stages of the species studied during this study were assessed using the following classification:

Stage I:	Immature	Sexes not distinguishable in the field.
Stage II:	Virgin	*Females:* ovaries narrow, cylindrical and transparent. Oocytes small and granular *Males:* testes thin, threadlike and transparent.
Stage III:	Starting	*Females:* eggs small and whitish but in solid mass. The ovaries are becoming vascularised. *Males:* testes whitish, broader, becoming vascularised. Milt is released if the testes are cut and squeezed.
Stage IV:	Mature	*Females:* eggs large, yolky, whitish-yellow in colour, separating only when pressed firmly. Ovaries very large, filling most of the body cavity, and well vascularised. *Males:* testes large, white, highly vascularised, releasing milt when pressed.
Stage V:	Ripe	*Females:* ovaries large, turgid and full of large, yellow eggs. The eggs separate and are expelled easily when the ovaries are pressed. *Males:* testes are large, white, and produce copious quantities of milt under slight pressure.

SPAWNING HABITS

The three species studied here exhibit differing spawning behaviour and physiology, each suited to their preferred habitats.

The genus *Sarotherodon*, all mouth-brood fertlized eggs and larval young (TREWAVAS, 1973), while *Tilapia* spp. exhibit a range of brood-guarding behaviour.

Sarotherodon niloticus

Discrete nests are constructed and guarded prior to spawning. During the fertilisation of the eggs, the female collects them in her mouth and there is thus little delay between fertilisation and uptake.

Sarotherodon galilaeus

This species occupies a rather intermediate position between the other two large Cichlidae in the lake. Eggs are not taken directly into the adult's mouth when laid, but fertilisation and uptake of eggs are delayed until the clutch is complete. The eggs are somewhat sticky, which may assist their retention within the nest area during the delay prior to uptake. There is some difference of opinion as to whether both sexes of S. galilaeus brood the young (JOHNSON, 1974), but the majority of reports indicate that they are both involved.

Tilapia zillii

This species inhabits gravelly and rocky shores or, less frequently, bays with dense stands of Potamogeton pectinatus. The eggs are produced in sticky strands and are attached to firm substrates, including both rocks and plants. After hatching, the young are not brooded in their parents' mouths, but are guarded by both sexes (FRYER and ILES, 1972).

LENGTH AT FIRST MATURITY

The length at first maturity is defined as the minimum length at which gonadial development had advanced to at least Stage IV in 50% of individuals. The two species of Sarotherodon proved to be cylical breeders with no apparent resting stage, and the length at first maturity was easily recognisable.

FIRST MATURITY IN Sarotherodon niloticus

Most of the information on length at first maturity was derived from samples taken in Ferguson's Gulf. The smallest male S. niloticus was a fish of 24.5 cm TL. Figure 11.27 shows that above this size the proportion of mature fish rose steadily to reach 100% at a length of 34 cm TL. It is estimated from Figure 11.27 that 50% of the males were mature at 32.2 cm TL.

Similar results for females which are presented in Figure 11.28 show that the smallest mature female measured 24.5 cm TL. The increase in the proportion of mature fish with size was more irregular than in the males, but it is estimated that 50% of the females had matured at a length of 29.6 cm TL.

LOWE-McCONNELL (1958) reviews data on maturity in S. niloticus in various East African lakes and records a length at maturation of 39 cm for the Lake Turkana population, considerably higher than the values obtained in the present studies. In a similar way, she records a length of 28 cm for the maturation length of fish in Lake George, whereas GWAHABA (1973) observed that females matured at the comparatively small size of 20.5 cm TL. It would appear that length at maturity in S. niloticus may change with time, possibly as a result of changing environmental conditions, fishery pressure and similar external influences.

The data provided by LOWE-McCONNELL (op. cit.) indicates that the Lake Turkana population both matures at a larger size and grows to a greater maximum length than S. niloticus in other East African lakes. As reported previously, specimens of up to 64 cm TL have been obtained from Lake Turkana in the past, and a maximum size of 54 cm was observed during the present project. Elsewhere the highest maximum length quoted by LOWE-McCONNELL (op. cit.) was 42 cm in Lake Mobutu (formerly Lake Albert) where the population matured at a length of 28cm.

The smallest mature S. niloticus mentioned by LOWE-McCONNELL (op. cit.) inhabited a lagoon at Buhuka, Lake Mobutu (formerly Lake Albert) where females of 12 cm TL were breeding. A similar phenomenon, which is through to be an ecophenotypic effect, was observed during the present investigations at Loiengalani where S. niloticus was breeding at a length of only 8 cm TL in springs isolated from the main lake.

The extreme plasticity of S. niloticus was also demonstrated during the present project by fish which were caught as fry of 1-2 cm TL in Ferguson's Gulf and kept in an aquarium tank. The fish were sexually mature at 8 cm TL and approximately 7 months of age.

FIRST MATURITY in Sarotherodon galilaeus

Maturity data for S. galilaeus are illustrated in Figures 11.29-30. From these results it is estimated that males and females matured at mean lengths of 23.2 cm and 22.7 cm respectively.

JOHNSON (1974b) reviews literature on the maturity of S. galilaeus elsewhere. Most estimates for the length at maturity in females range from 16-22 cm TL, for example: Lake Mobutu (formerly Lake Albert), 16-17 cm (LOWE-McCONNELL, 1955); Lake Tiberias, 18-22 cm (BEN-TUVIA, 1959); Lake Volta, 19.8 cm (LELEK and WUDDAH, 1968).

FIRST MATURITY IN Tilapia zillii

It has not been proved possible to establish the length at 50% maturity in T. zillii due to the small number sampled and the wide overlap in size between immature and mature fish. Data, chiefly from Allia and El Molo Bays, are analysed in Table 11.46. Although mature males and females of only 8 cm were recorded, fish classed as immature were recorded up to a length of 24 cm in the case of females, and 27 cm in males. A possible explanation is that breeding was not continuous in T. zillii and that gonads reverted to a resting stage after spawning which was recorded as 'immature' during the collection of field data. An alternative possibility is that there was wide variation within the population in the length at which maturity was achieved.

RELATIONSHIP BETWEEN MATURITY AND MAXIMUM SIZE

Data relating length and weight at maturity to maximum size for the three species are presented in Table 11.47. The results indicate that the fish continue to grow actively after sexual maturity. Thus in S. niloticus males and females matured at approximately 60% of the maximum length and at 13% of the total weight. In the case of T. zillii mature males were recorded at a weight equivalent to only 1.7% of their maximum weight. Whether such fish continue to grow to a size approaching the maximum size is unknown. It is possible that they may represent a 'dwarf' or neotonic group within the main population.

BREEDING CYCLES

No resting stage was discernable in the large cichlids after fish had reached maturity. Recently spawned or spent individuals were recognisable by flaccid, well vascularised gonads containing residual eggs or milt. The gonads of such recently spawned fish started a further cycle of gamete production immediately.

The time taken for young fish to complete growth and development up to first maturity has been discussed above. It seems likely that the initial cycle of gonadial maturation was accomplished more rapidly than was the case in succeeding breeding cycles. During the preliminaries to spawning and brooding, both males and females fed intermittently (see page 1358). Considerable energy losses at this time would require replenishment between spawning phases. Fish continued to grow after the attainment of maturity, and further energy would be expended in this field.

SEASONALITY OF BREEDING

The foregoing account has described how seasonally high survival of S. niloticus fry in Ferguson's Gulf modified population structure so that a distinct size cohort was formed. This dominant size group of fish tended to mature together at the same time of the year and it would be expected that such recruitment into the breeding stock would have led to a considerable seasonal increase in spawning activity. It is believed, however, that the density of spawning S. niloticus in Ferguson's Gulf was dependent more on the availability of spawning sites than on the number of fish which were potentially capable of spawning. Seasonal gonadial data for S. niloticus were obtained chiefly from catches in the vicinity of the meteorological station near the mouth of Ferguson's Gulf, well away from the spawning grounds in the south-eastern corner (Table 11.48). Very few fish of adult size occurred in the catches during the latter half of the year. Fish in breeding conditions were present throughout the year, but the proportion was particularly low in February. There was, however, no supporting evidence to show that spawning activity was low during this particular month, and routine observations on the occurrence of early fry in foot seine catches suggest that breeding continued throughout the year without any marked fluctuations.

MORIARTY (1973) described two main breeding periods for S. niloticus in Lake George which corresponded to the rainy seasons, March-May and September-December. Spawning fish were, however, found throughout the year, with up to 35% of females active during the dry seasons. HYDER (1970) suggested that Sarotherodon leucostictus in Lake Naivasha was stimulated to breed by rain while gonadial development was probably influenced by sunshine and water temperature.

JOHNSON (1974) reviews breeding in Sarotherodon and Tilapia and reports that in many African lakes seasonal breeding is not evident. Temperate water populations, as for example S. galilaeus in Lake Tiberias, breed seasonally, but the periods of activity may be prolonged and poorly defined.

In Lake Turkana, temperatures were remarkably stable and rainfall irregular, but a possible influence on the breeding of large cichlids cannot be ruled out completely in view of the sharp falls in temperature recorded in shallow water during the infrequent rain storms.

FECUNDITY

Counts of eggs present in ripe females were recorded for twelve S. niloticus ranging from 24.5 to 40.5 cm TL, and for twelve S. galilaeus of 20.2 to 31.8 cm TL. Results are illustrated in Figures 11.31 and 11.32. The relationship between length of fish and the number of eggs produced is usually exponential. By calculating a regression of log egg number on length (1) for each species, the following expressions have been obtained:

S. niloticus

$$\log \text{Egg No} = 0.021x + 2.6 \quad (r^2 = 0.80,\ n = 11)$$

S. galilaeus

$$\log \text{Egg No} = 0.025x + 2.75 \quad (r^2 = 0.86,\ n = 11)$$

LOWE-McCONNELL (1955) has reviewed previous work on the fecundity of Tilapia and Sarotherodon spp. The present data (Figs. 11.31 and 11.32) indicate possibly greater egg production by Sarotherodon spp. in Lake Turkana than by fish of the same species breeding at similar lengths in other lakes.

SEX RATIO

During the present investigations, more than 3000 S. niloticus ranging from 16 to 55 cm TL were sexed. The sex ratio (expressed as number of females per 100 males) for the entire sample was almost exactly 100, indicating that similar numbers of males and females were present. An analysis of data on the basis of size (Table 11.49) showed that at lengths below 35 cm TL, females were slightly more numerous than males. The proportion of females declined appreciably in larger length classes, and none of the 27 largest S. niloticus above 51 cm TL was a female. The results suggest either higher mortality or a lower growth rate in the females.

Similar results for S. galilaeus are shown in Table 11.50. Females slightly outnumbered males in the lower length classes, but there was a slight preponderance of males at lengths of over 26 cm TL.

In the case of T. zillii, observations were limited to a total of 114 fish. There was no evidence of the proportion of males increasing with length or of sex ratio varying in different size classes.

WORTHINGTON and RICARDO (1936) were the first to record the dearth of females among large S. niloticus in Lake Turkana. Similar observations on the Lake Turkana population were made by LOWE-McCONNELL (1958) who reported that no such sexual differences were apparent in either Lake George or Lake Edward. The latter lakes were already subject to commercial exploitation, and it is possible that heavy fishing mortality prevented fish from surviving to an age where a sexual size difference became evident.

FRYER and ILES (1972) note that males outgrow females in several species of Sarotherodon and BAILEY et al (1976) report a similar situation for both S. jipe and S. pangani in the newly formed Nyumba ya Mungu reservoir.

THE EFFECT OF FISHING PRESSURE ON *Sarotherodon niloticus* IN LAKE TURKANA AND OTHER WATERS

There is no evidence to suggest that commercial fishing pressure on *S. niloticus* in Lake Turkana results in maturation at a shorter size than would be the case were the population not exploited.

Since the main cichlid fishery, Ferguson's Gulf, is greatly reliant upon physical and meteorological conditions for providing high fry survival (see later), and since these conditions do not prevail every year, the exploited fishery will continue to be spasmodic, lasting only for one to two years after maximum fry survival, if not replenished.

Sustained high fishing pressure on a permanent *S. niloticus* fishery, however, may be an important factor in the reduction of length at first maturity. In Lake George, increased fishing pressure and increasing use of small-meshed nets have resulted in a reduction in the length at first maturity of female *S. niloticus* (GWAHABA, 1973). In 1957-1959, the 50% maturity length was ca 24.6 cm TL (FRY and KIMSEY, 1959), while in 1971-1972, the corresponding length was 20.5 cm. This evidence is vital to the maintenance of a healthy *Sarotherodon* fishery in the gulf if conditions are favourable enough to sustain high fry survival for a number of years.

LOWE-McCONNELL (1958) reports earlier length decreases in these populations in Lake George from 1949-1952, but this was probably due to the removal of older fish which were not exploited during this 'closed' period. Her method for length at maturity determinations for the Lake Turkana population is not stated, but she reports both sexes to mature at ca 39 cm TL. In the present study, 100% maturation is achieved between 34 and 36 cm TL (Figures 11.27 and 11.28) by both sexes. This represents a probable change in length of 3-4 cm between the maturation sizes of the poorly exploited stock of 1953 and the heavily fished population of 1973-1975, mainly through changes in pressure on breeding areas, rather than to sustained intensity of fishing.

With the gazetting of a National Park on the eastern shore of Lake Turkana (Fig.1.2) a very large area of sheltered shoreline is restricted and fishing prohibited. Features of sites sampled in this region are shown in the first Chapter (Fig. 1.2), and is very important to fish breeding or living in inshore regions (see Chapter 2).

The Park includes both rocky and sandy shores, with steep and shallow gradients, mud and gravel substrates, thus representing a uniquely varied source of habitats that may act as a reserve for fish stocks exploited elsewhere in the lake.

A second area of major importance in this context is the rocky shoreline of the Southern Sector. While most of the region is of high energy steep shoreline, there is still a rich food source of loosened 'aufwuchs' against the western shore, and dense epilithic growths on more sheltered eastern shores. Within such sheltered sites, for example on the west side of South Island, to the north of Mugurr, and at several places between Porr Point and the extreme southern end of the lake (Fig. 1.2), high numbers of fry would indicate an actively breeding population which, again, would act as conservation and recruitment centres. These populations may be protected from exploitation by the very extreme natures of their habitat, but some active legislation to preserve such stocks would be advisable if they are to remain 'conservation' sources.

THE EXPLOSIVE INCREASE IN COMMERCIAL CATCHES OF Sarotherodon niloticus IN FERGUSON'S GULF

As noted in the introductory remarks, catches of S. niloticus rose phenomenally between 1974 and 1976 (Table 11.39) as the result of an explosive increase in the Ferguson's Gulf population of this species. Explanations for this sudden proliferation are now considered.

Turkana District is arid and peopled by nomadic pastoralists. When grazing becomes depleted, stock is driven to permanent grazing sites, sometimes around waterholes or dry river beds, but more often in localised areas on the west shore of Lake Turkana, including Ferguson's Gulf. The main 'dry season' from January to April coincides with a seasonal fall in lake level (see Chapter 1) which results in the exposure of an extensive, damp, fertile plain on the southern and western margins of Ferguson's Gulf. The recently exposed plain develops an extensive cover of the grasses Sporobulus spicatus and Cyperus laevigatus, providing vital grazing for the Turkana stock if regions inland remain dry as was the case during 1972 and 1973. In early 1976, rainfall in the vicinity of Kalokol and Longech Spit was similar to that of previous years (see Chapter 1), but very heavy rains fell inland, away from the lake. These rains were well spaced temporally and provided ideal conditions for the Chrysopogon grass community and, in turn, for stock. In consequence, there was little pressure on the pastures bordering the southern and western margins of Ferguson's Gulf which had developed as usual on fertile areas exposed by the receding lake. At the onset of the 1976 Omo flood season, the area was fairly densely vegetated and only lightly grazed. As the lake level rose between July and October, the vegetation became inundated, providing optimal nursery grounds for young Sarotherodon. The plants formed dense cover in very shallow water and provided a further substrate which was colonised by attached algae, for example Rhopalodis spp. It is estimated that shallow grassy marsh formed a marginal belt along the shore of the gulf up to 800 m wide which covered an area of ca 10 km^2.

The period from July to October thus represented a time of unusually high fry survival, when cover and food were plentiful. The circumstances which led to favourable conditions for Sarotherdon survival during 1974 were repeated in 1975. Well-spaced rains away from the lake again relieved grazing pressure on the grassy plain bordering Ferguson's Gulf, leading in turn to the re-establishment of extensive shallow-water marshes when the lake level rose in July.

Figure 11.33 illustrates the results of a fry survey performed in Ferguson's Gulf from July 1975 to June 1976. Maximum numbers of S. niloticus fry were recorded during April, May, June and July, which may seem paradoxical in view of the foregoing remarks. The explanation is that during the low water season the fry lacked shelter and concentrated in a narrow zone, up to about 10 metres wide, along the lake shore. With the creation of a wide marginal zone of shelter up to 800 m wide during the flood season, the young fish were dispersed over a much wider area at lower population densities.

Figure 11.34 compares the seasonal changes which occur in marginal areas of Ferguson's Gulf during years when the lake inundates grassy plains with years when the lake rises over bare flats of silty mud. Under the latter circumstances environmental conditions for Sarotherodon fry vary but little during the course of the year. Such conditions were noted during both 1972 and 1973 and are probably characteristic of years when grazing pressure is high during the pre-flood season.

PETR (1967) stressed the importance of marginal vegetation to young cichlids in Lake Volta. Marked increases in populations of Sarotherodon and Tilapia spp. were recorded in the lake during the first 16 months after its formation. This burst of activity was attributed to high water levels in the second half of 1964 providing optimal development conditions for the fry among flooded grass and bushes.

FACTORS CONTRIBUTING TO THE SUCCESS OF Sarotherodon niloticus IN FERGUSON'S GULF

The genetic plasticity and the ability of cichlids to inhabit an extremely wide range of habitats are two key factors in their well-documented success (FRYER and ILES, 1972). Most species are herbivorous or detritivorous and are usually separated from the primary producers by only one, or at the most two, steps in the food chain.

The phytophagous diet of Sarotherodon niloticus combined with its habit of mouth-brooding have undoubtedly been instrumental in bringing about the recent dramatic population increase in Ferguson's Gulf. Phytophagy is clearly advantageous in such a shallow, enclosed body of water rich in phytoplankton. High levels of algal production in the gulf are sustained from year to year by relatively constant limnological conditions, and availability of food is not considered to be a limiting factor for S. niloticus. As shown in the succeeding section on food (page 1363) these fish are capable of utilising the dominant blue-green algal content of the plankton.

The breeding habits of S. niloticus have enabled it to spawn within the gulf and to produce a constant supply of fry regardless of season. Small fish are therefore always present to take advantage of favourable environmental conditions which might occur only spasmodically. For this reason, S. niloticus has been able to profit from the excellent nursery grounds provided by the inundated grassland discussed at length above. The dense forest of marsh grasses provide fry with a refuge against predatory fish.

WELCOMME (1964) has shown that the ability of cichlid fry in Lake Victoria to withstand conditions of high temperature and lowered oxygen tensions in marginal areas of the lake are important adaptations with high survival value. In Ferguson's Gulf, the fry of Sarotherodon niloticus clearly benefit from such capabilities. They were able to tolerate the unusually high temperatures and low oxygen concentrations which prevailed almost daily during calm afternoons in shallow water close inshore. These harsh conditions excluded potential competitors and predators.

THE PREDICTION OF FUTURE YIELDS IN THE FERGUSON'S GULF *Sarotherodon* FISHERY

Future yields of the Ferguson's Gulf fishery for *S. niloticus* are difficult to predict. There seems little doubt that the recent dramatic rise in catch has been due to high survival rates of fry among the grassy vegetation which was a feature of the margins of the gulf during 1974 and 1975. If this is true, then a return to pre-1974 conditions with heavy pre-flood grazing by domestic stock on the margins of the gulf should result in a considerable increase in fry mortality followed by a drastic fall in commercial catches. Under such circumstances, the future of the fishery is clearly dependent on meteorological and socio-ecological factors. If optimum conditions for fry survival persist, predictive techniques are possible. HENDERSON and WELCOMME (1974) have provided a regression for exploited African lakes of yield against morphoedaphic index (MEI):

$$\text{Maximum yield (kg/ha)} = 14.314\ \text{MEI} - 0.47 \qquad \text{(i)}$$

The morphoedaphic index for Ferguson's Gulf may be calculated from the following expression quoted by RYDER (1964):

$$\text{MEI} = \frac{\text{Conductivity } (\mu\text{S/cm})}{\text{Mean depth (m)}} \qquad \text{(ii)}$$

$$= \frac{3700}{2.5} \quad = \quad 1480$$

This would indicate maximum yield of about 21,000 kg/ha for Ferguson's Gulf which is close to the value of 16,000 kg/ha estimated for 1976. The 1976 estimate was based on a total catch of 16,000 tonnes derived from an area of 10 km covered by the feeding zone in the south-eastern third of the gulf.

Predictions from photosynthetic activity of phytoplankton have also been made for temperate and tropical freshwater habitats. MELACK (1976) provides the following regression equation for African lakes:

$$\log \text{Fish yield (kg/ha/annum)} = 0.113\ \text{PG} + 0.91 \qquad \text{(iii)}$$

where PG = gross photosynthetic rate in $gO_2/m^2.12$ hrs

A value of 11.53 was obtained for PG for Ferguson's Gulf (see Chapter 2) and fish yield is thus predicted to be 163 kg/ha/annum. The equation is clearly unacceptable as a predictive tool for Ferguson's Gulf. A similar method proposed by McCONNELL *et al* (1977) also fails to give reasonable estimates of the gulf's potential.

The continuation of the *S. niloticus* fishery at the high 1976 level under optimal climatic conditions may eventually lead to limitations imposed by nutrient depletion. Three major sources of nutrient have been recognised in Ferguson's Gulf.

(i) Allochthonous sources including the catchments of the Kalokol and Kalorukongole Rivers and marginal areas of the actual gulf. Rainstorms followed by flooding are responsible for the transport of dissolved and suspended organic material from these sources into the gulf.

(ii) Wind induced currents with relatively high nutrient levels, which flow into the north-eastern corner of the gulf from the open lake and depart in a northerly diretion up the west shore after circulating round the southern margin.

(iii) Heterocystous blue-green alge which dominate the phytoplankton of the gulf and assimilate atmospheric nitrogen. This type of alga is particularly successful in environments such as Ferguson's Gulf, where soluble orthophosphate-phosphorus is present in non-limiting quantities.

Although it seems likely that a combination of the three main sources are capable of providing the principal nutritional requirements for the maintenance of the fishery at its current levels, it is not known to what extent essential minor nutrients have been removed from the ecosystem by heavy cropping of fish.

Long-term prospects for the Sarotherodon fishery in Ferguson's Gulf are threatened by gradual silting up (see Chapter 1, page 11). There is evidence to show that this process is accelerated by the erosion of the tip of Longech Spit. Eroded material is carried into the gulf by the circulatory currents alluded to above. Sedimentation of the suspended material occurs within the gulf. A net rise or fall in mean lake level resulting from the affects of climatic change on the discharge of the River Omo would clearly modify the effects of silt deposition in Ferguson's Gulf.

SUMMARY

Of the seven species of cichlid fish recorded from Lake Turkana, only the three largest species, Sarotherodon niloticus, Sarotherodon galilaeus and Tilapia zillii are of actual or potential commercial importance. This paper details results of studies on these fish from mid 1972 to early 1976.

Sheltered, inshore regions of the lake support the densest populations of all three species, but not all such areas are fished, suggesting that some potential conservation and recruitment sources exist.

In Lake Turkana, these cichlids attain larger sizes than reported elsewhere and earlier reports of this phenomenon are substantiated here. Indirect evidence of their growth rates suggests that they are all inhabiting near-ideal environments and that they grow nearly as rapidly in the lake as they do in very carefully controlled pond-trials elsewhere in East Africa.

Sarotherodon niloticus is the dominant species of large cichlid, and explanations for the high fry survival and explosive expansion of a fishery based on this fish, in Ferguson's Gulf, are given.

REFERENCES

BAILEY, R G, CHURCHFIELD, S and PIM, R (1976). The Fish Biology. In Denny, P and Bailey, R G. *A biological survey of Nyumba ya Mungu Reservoir, Tanzania, July to September 1974*. Fisheries Division, Government of Tanzania.

BALON, E K (1974). Fish production in a tropical ecosystem. In Balon, E K and Coche, A G (Eds), *Lake Kariba: a man-made tropical ecoystem in Central Africa*. Junk, The Hague. 676 pp.

BAYLEY, P B (1976). Changes in fish species composition of the yields and the development of the fishery of Lake Rudolf, Kenya. *Archiv. fur Hydrobiol*. *79* : 111-132.

BEN-TUVIA, A (1959). The biology of the cichlid fishes of Lakes Tiberias and Huleh. *Bull. Res. Coun. Isr*. *8b* : 153-188.

BLACHE, J (1966). *Les poissons du bassin du Tchad et du bassin adjacent due Mayo-Kebbi*. Paris, O.R.S.T.O.M. 483 pp.

DUNN, I G (1972). *Ecological studies on the fish of Lake George, Uganda: with particular reference to the cichlid genus Haplochromis*. PhD Thesis, University of London.

EAST AFRICAN INLAND FISHERIES RESEARCH ORGANISTION (1950). *Report for 1949*, 13 pp. East Africa High Commission.

FISCHELSON, L (1966). Untersuchungen zur vergleichenden Entwicklungs gesichichte der Gattung *Tilapia* (Cichlidae, Teleostei). *Zool. Jb. Ana*. *83* : 571-656.

FRY, D H and KIMSEY, J B (1960). *Report on the Fisheries of Lake George, Uganda*. (Unpublished, Internal FAO report).

FRYER, G and ILES, T D (1977). *The cichlid fishes of the Great Lakes of Africa*. Oliver and Boyd, Edinburgh. 641 pp.

GWAHABA, J J (1973). Effects of fishing on the *Tilapia nilotica* (Linne, 1757) population in Lake George, Uganda over the past 20 years. *E. Afr. Wildl. J*. *11* : 317-328.

HARBOTT, B J (1975). Preliminary observations on the feeding of *Tilapia nilotica* Linn. in Lake Rudolf. *Afr. J. Trop. Hydrobiol. Fish*. *4* : 27-37.

HENDERSON, H F and WELCOMME, R L (1974). The relationship of yield to morphoedaphic index and numbers of fishermen in African inland fisheries. *CIFA Occasional Paper No 1*. *FAO, Rome* : 1-19

HOPSON, A J (1972). A Study of the Nile Perch (*Lates niloticus*) (L) (Pisces: Centropomidae) in Lake Chad. *Overseas Res. Publ*. *19* : 93 pp. HMSO, London.

HOPSON, J (1972). Breeding and growth in two populations of *Alestes baremose* (Joannis) (Pisces: Characidae) from the northern basin of Lake Chad. *Overseas Res. Publ*. *20* : 50 pp. HMSO, London.

HYDER, M (1970). Gonadial and reproductive patterns in *Tilapia leucosticta* (Teleostei-Cichlidae) in an equatorial lake, Lake Naivasha (Kenya). *J. Zool. London* *162* : 179-195.

JOHNSON, R P (1976). Synopsis of biological data on *Sarotherodon galilaeus*. *FAO Fisheries Synopsis No 90*. FAO, Rome.

KRUPKA, J (1974). The Kurper Bream *Sarotherodon mossambicus* mortimeri (Trewavas, 1966). In Balon, E K, and Coche, A G (Eds). *Lake Karibia: A man-made tropical ecosystem in Central Africa*. Junk, The Hague. 676 pp.

LELEK, A (1972). *Fish populations of Kainji Lake, trends in their development and utilisation*. Kainji Lake Research Project, Nigeria. FAO, Rome, FI: SF/NIR24 Tech. Rep. *2* : 121 p.

LELEK, A and WUDDAH, A A (1968). Contribution to the maturity and fecundity of *Tilapia galilea* (Linnaeus) in the Volta Lake. *Vestn. Cesk. Zemed. Mus.* *32* : 342-349.

LOWE, R H (1955). The fecundity of *Tilapia* species. *East Afric. agric. J.* *10* : 256-262.

LOWE-McCONNELL, R H (1958). Observations on the biology of *Tilapia nilotica* Linne in East African waters. *Rev. Zool. Bot. Afr.* *57* : 129-170.

LOWE-McCONNELL, R H (1975). *Fish communities in tropical freshwaters*. London, Longman. 337 pp.

MANN, M J (1964). Report of a fisheries survey of Lake Rudolf, Kenya. *Ann. Rep. E.Afr. freshw. Fish Res. Org. 1962/63*. 53-62.

MELACK, J M (1976). Primary productivity and fish yields in Tropical lakes. *Trans. Am. Fish. Soc.* *105*: 575-580

MORIARTY, C M (1973). *Feeding of herbivorous fish in Lake George, Uganda*. MPhil Thesis. University of Nottingham.

MORIARTY, D J W (1973). The physiology of digestion of blue-green algae in the cichlid fish, *Tilapia nilotica*. *J.Zool. Lond.* *171* : 25-40.

PETERSEN, C G J (1892). Fiskenbiologiske forhold; Holboek Fjord, 1890-91. *Beretning fra de Danske Biologiske Station for 1890(91)*. *1* : 121-183.

PETR, T (1967). Food preferences of the commercial fishes of the Volta Lake. *Tech. Rep. Volta Basin Res. Proj. Univ. Ghana.* *(X22)*. 7pp.

RHODES, D H (1966). *Fisheries development possibilities (Fishery of Lake Rudolf)*. UNDO/FAO Rep. No TA2144/E. 77pp.

RINNE, J N (1975). Fish tagging experiments - a prelude to an extensive tag-recovery programme on Lake Victoria. *Afr. J. Trop. Hydrobiol. Fish* *4* : 1-19.

RINNE, J N (1975). Fish tagging experiments - a prelude to an extensive tag-recovery programme on Lake Victoria. Afr. J. Trop. Hydrobiol. Fish 4 : 1-19.

RINNE, J N (1976). Coded spine-clipping to identify individuals of the spiny-rayed fish *Tilapia*. J. Fish. Res. Board Can. 33 : 2626-2629.

TAUBERT, B D and COBLE, D W (1977). Daily rings in Otoliths of three species of *Lepomis* and *Tilapia mossambica*. J. Fish. Res. Board Can. 34 : 332-340.

TESCH, F W (1968). In Ricker, W E (Ed). Methods for assessment of fish production in fresh waters. Oxford, Blackwell.

TRENCH, C C (1966). Lake Rudolf. Geog. Mag. 38 : 729-739.

TREWAVAS, E (1933). Scientific results of the Cambridge expedition to the East African Lakes, 1930-31. 11. The Cichlid Fishes. J. Linn. Soc. Lond.(Zool). 38 : 309-341.

TREWAVAS, E (1973). On the cichlid fishes of the genus *Pelmatochromis* with proposal of a new genus for *P. congicus*; on the relationship between *Pelmatochromis* and *Tilapia* and the recognition of *Sarotherodon* as a distinct genus. Bull. Br. Mus. nat. Hist.(Zool) 25 : 1-26.

VAAS, K F and HOFSTEDE, A E (1952). Studies on *Tilapia mossambica* Peters (Kan Mudjair) in Indonesia. Pember. Balai Besar Penjel, Pertan. 1 : 1-68.

VAN SOMEREN, V D and WHITEHEAD, P J (1959). The culture of *Tilapia nigra* (Gunther) in ponds. I - Growth after maturity in male *T. nigra*. E. Afr. agric. J. 25 : 42-46.

VAN SOMEREN, V D and WHITEHEAD, P J (1960a). The culture of *Tilapia nigra* (Gunther) in ponds. III - The early growth of males and females at comparable stocking rates, and the length/weight relationship. E. Afr. agric. J. 25 : 169-173.

VAN SOMEREN, V D and WHITEHEAD, P J (1960b). The culture of *Tilapia nigra* (Gunther) in ponds. V - The effect of progressive alterations in stocking density on the growth of male *T. nigra*. E. Afr. agric. J. 26 : 145-155.

WELCOMME, R L (1964). The habitats and habitat preferences of the young of the Lake Victoria *Tilapia* (Pisces-Cichlidae). Rev. Zool. Bot. afr. 70 : 1-28.

WORTHINGTON, E B and RICARDO, C K (1936). Scientific results of the Cambridge Expedition to the East African Lakes, 1930-31. The fish of Lake Rudolf and Lake Baringo. J.Linn. Soc (Zool). 39 : 353-389.

STUDIES ON THE FEEDING ACTIVITY OF Sarotherodon niloticus (L) IN LAKE TURKANA

B J Harbott

INTRODUCTION

MATERIALS AND METHODS

RESULTS

- Subjective observations
- Determination of the weight of stomach contents
- Estimation of absolute quantity of food ingested per feeding cycle
- Discussion of results
- Selectivity of feeding by adult *Sarotherodon niloticus*
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- Food of *Sarotherodon niloticus* outside Ferguson's Gulf
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  - Introduction
  - Diel changes in food intake
  - Relative abundance of food items in the gut and in the environment

A NOTE ON THE FOOD OF *Sarotherodon galilaeus* and *Tilapia zillii*

- *Sarotherodon galilaeus*
- *Tilapia zillii*

SUMMARY

REFERENCES

INTRODUCTION

MORIARTY (1973) carried out a detailed study of the feeding habits of *Sarotherodon niloticus* in Lake George which placed particular emphasis on diel behaviour cycles. Since *S. niloticus* proved to be a diurnal feeder, it was possible to follow the build-up and progress of food in the gut during the course of a day and to provide accurate estimates of the dry weight of food ingested over a 24 hour period (see also EGGERS, 1977; JENKINS and GREEN, 1977).

Similar observations on *S. niloticus* were carried out during the present survey of Lake Turkana and a description of preliminary findings has been published (HARBOTT, 1975). The present account is based on the earlier observations augmented with additional data. Diel feeding cycles in S. niloticus prey, qualitative aspects of the food, and the assimilation of blue-green algae are also discussed. Most of the material was obtained from the vicinity of Ferguson's Gulf, but the food of fish from various localities, including the crater lakes of Central Island, has also been analysed.

MATERIAL AND METHODS

Quantitative analysis of diel changes in the food intake of adult and adolescent S. niloticus were based on a total of 350+ fish ranging from 18 to 46 cm TL caught in beach seines. Most material was obtained from the Ferguson's Gulf area, augmented by small samples from Allia, Moite and Eliye. Sampling was carried out throughout the full 24 hour period, and in each case, the time of capture was recorded. Owing to the difficulty in obtaining regular samples of fish from a particular site at all times of the day and night, data for a given time of day have been combined from various sampling sites and treated as a single population.

Total length and weight (in grammes) were recorded immediately after capture. The stomachs and intestines of each fish were then removed and treated separately. In certain cases gut contents were removed for pH measurements using a portable pH meter and glass electrode. The material was then suspended on Magnesium carbonate covered glass fibre filter discs before the proportions of phaeophytin a and chlorophyll a were determined. A modification of the method described by GOLTERMAN (1969) was used. In most instances, however, the dry weights of stomach and intestine contents were measured in grammes after drying to constant weight at 70°C.

Breeding and brooding activity were found to curtail food intake. Fish in such a sexually active state were excluded from the present determinations.

Techniques used during the present study differed in certain respects from methods described by MORIARTY (op. cit.). At the onset of feeding, stomachs and foregut were generally empty, while the hindgut contained very dark material, the residue from the previous day's feeding. MORIARTY (op. cit.) reported that the first food to pass from stomach to intestine each day was bright green, and thus clearly distinguishable from food ingested at the end of the previous cycle. She also noted an empty zone in the intestine, between fresh and residual food. No such colour delineation was evident in intestines examined during the present study, although a zone was observed to be more or less clear of solid material. This is probably analgous to the empty region described for fish in Lake George.

Whole intestinal contents were weighed during the present study and no attempt was made to differentiate between fresh and residual material until results were analysed. The method used in the current investigations is based on the following assumptions:

(1) At the commencement of feeding, the stomach and foregut were empty.

(2) The hindgut always contained some food.

(3) When feeding commenced, the stomach gradually filled, reaching capacity at the time when feeding ceased.

(4) During feeding, some food passed directly into the intestine without resting for long periods in the stomach.

(5) Food passed from stomach to intestine at a constant rate during the feeding period.

(6) The intestine first became full of newly ingested food when the empty region reached the anus. This took place at approximately 13.00 hrs each day.

RESULTS

SUBJECTIVE OBSERVATIONS

As a preliminary to detailed measurements of food intake, the stomach fullness of all adolescent and adult fish which were examined from beach seine samples during the present study was assessed on an eight point scale ranging from 0 (empty) to 8 (full) and corrected to percentage fullness. The results were classified according to the time of capture and a mean value of percentage fullness was calculated for each successive period of the 24-hour cycle. The results (Fig. 11.35) show that *S. niloticus* follows a marked diel pattern of feeding with the amount of food in the stomach rising steadily throughout the day to reach a peak at about 17.00 hrs. The percentage fullness shows a sharp decline after dark.

Figure 11.36 summarises the percentage of empty stomachs recorded from larger fish caught with beach seines at various times and sites. No empty stomachs were generally observed after 13.30 hrs each day.

DETERMINATION OF THE WEIGHT OF STOMACH CONTENTS

Table 11.51 summarises the relationship between wet weight of fish and dry weight of stomach contents at different times of the day. The relative weight of food increased steadily through the hours of daylight to reach a peak between 17.00 and 18.00 hrs. Excellent correlations between weight of fish and weight of stomach contents were also obtained for the same late afternoon period, and it is considered that the stomachs were 100% full. All data for a total of 52 fish sampled between 17.00 and 18.00 hrs were therefore combined (Fig. 11.37) and the following expression was obtained for the regression of dry weight of 100% full stomach contents on wet weight of fish:

$$\log y = 0.726 \log x + 0.9264 \quad (r^2 = 0.71)$$

From this relationship the percentage fullness on a dry weight basis was calculated for each fish. Combined results with a mean value of percentage fullness calculated for each sampling time are shown in Figure 11.38. Percentage fullness is plotted on a logarithmic axis and the relationship between this value and time (in hours) is expressed by the regression

$$\log y = 0.1115x + 0.098 \quad (r^2 = 0.96)$$

From Figures 11.37 and 11.38 it is now possible to determine the predicted dry weight of stomach content for fish of a given weight at any given time during the feeding cycle.

DETERMINATION OF THE WEIGHT OF INTESTINAL CONTENTS

Having ascertained that the stomachs reached peak fullness at between 17.00 and 18.00 hrs daily, similar procedures were used to estimate rates of change in the dry weight of intestine contents. Figure 11.39 illustrates the relationship between wet weight of fish and dry weight of intestine contents in samples from the same late afternoon period. The regression is described by the equation:

$$\log y = 1.184 \log x + 0.102 \qquad (r^2 = 0.87)$$

When mean percentage fullness for each time period is calculated (Fig. 11.40) no straightforward trend is visible throughout the feeding cycle. From ca 06.00 to ca 13.30 hrs there is a net gain in dry weight of intestine contents indicating that food entered faster than the defaecation rate. The relationship between time and mean percentage fullness before 13.30 hrs is expressed by the equation:

$$y = 12.33x - 22.8 \qquad (r^2 = 0.88)$$

After ca 13.30 hrs, there was a gradual net decrease in percentage fullness described by the equation:

$$y = -17.3x + 396.4 \qquad (r^2 = 0.98)$$

Thus, the predicted dry weight of intestine contents can be calculated for any wet weight of fish at any particular time in the feeding cycle.

ESTIMATION OF ABSOLUTE QUANTITY OF FOOD INGESTED PER FEEDING CYCLE

Using an idealised model (Fig. 11.41), similar to that of MORIARTY (1973), constructed from the results described earlier, it is possible to calculate rates of fresh food entering the gut. The following symbols (Fig. 11.41) have been employed:

t_0 = time of onset of feeding activity. The stomach and pre-gut are empty while the hindgut contains food from the previous day's feeding cycle

t_1 = time when intestinal contents reach a maximum and the intestine first becomes full of fresh material

t_2 = time when stomach contents are maximal and feeding ceases.

Stomach

The net rate at which the stomach fills (in gm dry weight food/h) is equivalent to

$$\frac{w_2 - w_0}{t_2 - t_0}$$

where w_2 is the predicted quantity of food accumulating in the stomach per feeding cycle. This process is represented in Figure 11.41 by line D-E.

Point A (w_1) represents the quantity of intestine contents at t_0. Since this material is residual food from the previous day situated in the hindgut, the amount of fresh food in the intestine is nil (w_0).

Point B (w_3) represents the time when the intestine initially fills with fresh food. The rate of entry and accumulation of fresh food into the stomach is equivalent to:

$$\frac{w_3 - w_0}{t_1 - t_0} \qquad \text{gm dry weight/h}$$

From t_1 onwards, defaecation results in a net loss of material from the intestine. If it is accepted that stomach evacuation rates are constant then the extrapolation of line D-B to point C at t represents the quantity of fresh material accumulated in the intestine, had no defaecation taken place. Total daily ingestion thus comprises w_2 (stomach) plus w_4 (intestine).

From Figures 11.38 and 11.40 it is evident that the duration of the daily feeding cycle of adult S. niloticus was approximately 11.75 h, from ca 06.45 hrs to ca 18.30 hrs. Maximum stomach fullness of 104% (w_2) was recorded at 18.30 hrs and intestinal contents reached a peak of 158% (w_3) at 13.30 hrs.

The extrapolation of line DB to poinc C (w_3) indicates that the total daily input of food into the intestine is equivalent to 275% of the amount contained in the full intestine. Thus, total daily ingested dry weights can be calculated (Table 11.52, Fig. 11.42).

The relationship between wet weight (gm) of S. niloticus and dry weight (gm) of food ingested daily is described by

$$y = 0.013x - 0.31$$

DISCUSSION OF RESULTS

In the preliminary report on the feeding of S. niloticus in Lake Turkana (HARBOTT, 1975) gut contents were calculated in proportion to the dry body weight of the fish where for fishes of 18.5-25.5 cm TL:

dry weight of S. niloticus = 27.96 ± 1.22% wet weight

The present study is based on material from preliminary observations plus results from a wider size range of fish obtained later during the project. Both estimates are in close agreement with the results of MORIARTY (1973) when values are calculated in absolute terms (Table 11.53). Populations in Lake Turkana and Lake George thus ingested a daily quantity of food, the dry weight of which formed between 1.1% and 1.4% of the wet weight of the fish.

Comparisons on a dry weight basis have not been made since MORIARTY (op. cit.) indicates an increase in dry weight as a proportion of wet weight in mature *S. niloticus* and the relevant data are not available for the Lake Turkana population.

SELECTIVITY OF FEEDING BY ADULT *Sarotherodon niloticus*

Examinations of the stomachs from over 50 adult *S. niloticus* of 24.2 to 35.6 cm TL caught in Ferguson's Gulf in April 1975 provided information to assess selectivity of adult fish feeding. Table 11.57 lists the percentage total occurrence of stomach contents from these fish. Most had ingested the main species of blue-green algae, diatoms and green algae, and few stomachs contained obscure, rare species. Invertebrate remains were not commonly found, and less than 3% of the stomachs examined contained zooplankton.

As percentages of total algal counts (Table 11.58) and total algal volumes (Table 11.59) show, results from stomach contents were very close to the quantities and proportions available in the plankton. Of the nine major species listed, *Anabaena circinalis* and *Spirulina platensis* were more common in the stomachs than in the plankton, while *Nitzschia* spp. were less common. Volumetrically, blue-green algae accounted for over 94% of the total food ingested, with *Anabaena circinalis* and *Spirulina platensis* together forming over 89%.

DISRUPTION OF ALGAL CELLS DURING DIGESTION

During the daylight feeding period of adult *S. niloticus*, no change in food selectivity was noted. Observations on the constitution and appearance of gut contents indicate variations in the rate of digestion of different algae (Table 11.60). The fish examined came from hauls made at 17.00 hrs EAT from the northwest corner of Longech Spit.

Stomach

Most cells were intact, although some filaments appeared fractured.

Foregut

Anabaena filaments were all fractured and most cells were separate, showing distinct cystoplasmic degeneration. *Spirulina* filaments were 'fuzzy' in appearance as the cell walls were digested, and most cell contents appeared affected by enzyme action. Most of the diatoms appeared intact.

Midgut

No entire *Anabaena* cells were visible, but many empty cells occurred *Spirulina* filaments mostly appeared digested, with empty cells frequent. Most *Cyclotella* cells contained cytoplasm but less than 30% of the *Navicula* cells were intact.

Hindgut

No entire *Anabaena* cells were visible, and very few *Spirulina* cells intact. Most *Cyclotella* cells were entire, but more than 90% of the *Navicula* cells were clear.

The filamentous blue-green algae were broken down and digested more rapidly than diatoms which, as seen earlier, constitute very small percentages of the total gut contents by volume. These fish clearly utilised the dominant food item very rapidly. Observations from other sites inside Ferguson's Gulf indicate the process to be typical of S. niloticus. Earlier publications on the digestibility of blue-green algae (see HARBOTT, 1975) concluded that no breakdown was possible in the absence of cellulose enzyme in the gut. Such systems are not present in chordates, cullulose being broken down by gut flora. PREJS and BLASZCZYK (1977) recently reported bacterial cellulase activity in the guts of several fish, including Sarotherodon hybrids. This facility is of little consequence to fish ingesting blue-green algae, since cellulose does not form a major component of the cell walls.

From the work of MORIARTY (1973) and BOWEN (1976), it is clear that the primary factor lysing blue-green algal and bacterial cells is low pH. This conditions is produced in the stomach by hydrochloric acid secretion. HARBOTT (1975) indicated preliminary findings of pH determinations from the stomachs and intestines of S. niloticus in Lake Turkana.

Further investigtions with more experience in handling the material indicate that slightly lower pH levels are in fact present in the stomachs than recorded earlier. Previous minimum stomach contents pH levels of 2.56 were recorded at 18.30 hrs; more recent findings indicate levels below pH 1.8 as early as 11.00 hrs. Sarotherodon niloticus living in Crater Lake A on Central Island show similar cyclic stomach pH, reaching levels below 2.0 after 13.30 hrs.

FOOD OF Sarotherodon niloticus OUTSIDE FERGUSON'S GULF

Todenyang

Samples were obtained from a shallow sheltered bay with abundant macrophytes including Cyperus, Sporabolus, Paspalidium and Potamogeton. The algal composition of the food of S. niloticus from this area was similar to that of the phytoplankton (Table 11.61). The species concerned were chiefly diatoms which normally grow attached to the substrate or to macrophytes but are frequently dislodged by wave action and so enter the plankton.

Allia Bay

Algae growing attached to macrophytes and mud were common in the stomachs of S. niloticus in Allia Bay. The phytoplankton was clearly distinct from that of the main lake and this is reflected in the list of stomach contents (Table 11.62).

The crater lakes of Central Island

Populations of S. niloticus occurred in Crater Lakes A and C of Central Island. In Lake C, which was last joined to the main lake in 1972, the phytoplankton was typical of sheltered lagoon-type environments, with dense standing crops of blue-green algae. Species common in the phytoplankton were Anabaena circinalis, Spirulina platensis, Chroococcus minutus and Anomoneis sphaerophora. These species were similarly frequent in the guts of S. niloticus.

The north, west and southern shores of Lake C bore dense stands of Sporobolus spicatus which in turn maintained dense epiphytic algal communities. Fish in Lake C were healthy and in good condition.

This situation contrasted strongly with Crater Lake A where low concentrations of phytoplankton were observed and epilithic algae proved to be the main food source. Species recorded in the guts included *Calothrix javanica*, *Lyngbya lutea*, *Oscillatoria sphaerophora*, *Rhopalodia gibba* and *Surirella biseriata*. Stomachs also contained *Chroococcus minutus* and vorticellids.

Southern Lake

It is evident that *S. niloticus* living in regions with sparse phytoplankton crops are able to feed by scraping material from the substrate. This was also apparent from food analyses of *S. niloticus* caught in Loiengalani Bay and off the west shore of South Island, where contents were dominated by *Gomphocymbella beccari*, a raphe-bearing diatom which lives in dense almost uni-algal communities on such shores.

THE FEEDING HABITS OF *Sarotherodon niloticus* FRY

Introduction

The food of young *S. niloticus* ranging from 1.5 to 6.8 cm was investigated over a diel cycle at an inshore station at Met Bay, Longech, during March 1976. A total of 6 samples were obtained at intervals of approximately 4 hours during the 24 hour period. The number of fish examined for each sampling period is indicated in Table 11.54.

Diel changes in food intake

The fullness of each stomach was assessed on a subjective 8-point fullness scale where 0 = empty and 8 = full.

From these observations data were combined to give a value of mean fullness for each sampling period. The results for the full 24 hour cycle (Fig. 11.43) show a well marked diel feeding pattern with activity increasing considerably during the hours of daylight to reach a peak at 12.30 hrs. The most frequent category of food was phytoplankton, chiefly diatoms and blue-green algae. These were particularly important during the hours of daylight (Table 11.54 and Fig. 11.44) indicating that at this time feeding took place off the bottom. The high frequencies of *Rhopalodia* spp. do not necessarily conflict with mid-water feeding behaviour since these algae, although generally epibenthic, were frequently dislodged by wave action and in any case represent only a small proportion of the digested material.

Ingestion of invertebrates, and to a lesser extent protozoa, occurred only during the hours of darkness (Table 11.54). Generally fewer fish were feeding at this time (Fig. 11.43) but those with stomachs containing food had all ingested chironomid larvae or adult corixids. The indications are that fish fed as occasional browsers, selecting individual food items on the bottom during the hours of darkness.

Relative abundance of food items in the gut and the environment

Table 11.55 provides the numbers of nine major algal species as percentages of total algal counts in the plankton and stomachs of *S. niloticus*. There is generally close agreement between the two series except in the case of *Synechocystis aquatilis*, a unicellular blue-green alga, and Nitzschia spp., fine, generally solitary, raphe-bearing diatoms. The former appears to have been virtually ignored, while there was clearly significant selection for the latter.

Table 11.56 lists 14 species of algae occurring in the stomachs of fish ranging from 3.0-3.3 cm TL caught at 12.30 hrs. Mean numbers per stomach, absolute and percentage volumes are also given. The blue-green alga Spirulina laxissima and diatoms of the genus Nitzschia were the most important numerically, but Anabaena circinalis was the dominant food item in volumetric terms, forming over 72% of the total intake Blue-green algae as a whole formed 75% of the volume of food ingested, with diatoms contributing most of the remaining 25%.

Selectivity was also evident in the invertebrate prey of small S. niloticus in Ferguson's Gulf. Hand-net catches showed that cyclopoid copepods as well as corixids were common in the shallow water environment, but only corixids were noted in the food of the young fish (Table 11.54), suggesting that selection had occurred. MORIARTY (1973) noted that fish of comparable size in Lake George ingested similar proportions of zooplankters and phytoplankters. Copepodite stages were, however, rare in the food of the Lake George fish. The possibility that strong positive rheotaxis enabled copepods to avoid capture would have applied equally to corixids, which were frequently found in the stomachs of young S. niloticus in Ferguson's Gulf. The results indicate that preferential non-selection of zooplankters occurred.

A NOTE ON THE FOOD OF Sarotherodon galilaeus AND Tilapia zillii

Sarotherodon galilaeus

Limited data on the feeding habits of S. galilaeus show close parallels with S. niloticus. While no systematic study was possible, small numbers of individuals examined showed empty stomachs early in the day, gradually filling during daylight hours. Stomachs were half full by ca 12.00 hrs. Sarotherodon galilaeus were most frequently caught over muddy substrates rather than firmer sand, and this was reflected in the stomach contents.

Fish in Ferguson's Gulf ingested all the major members of the phytoplankton in similar proportions to what has been observed in S. niloticus. However, large quantities of detritus and bacteria were frequently recorded, indicating that this species fed closer to the substrate, at times ingesting the flocculent uppermost benthic layers, which often contain high quantities of detrital material originating from the phytoplankton. In other regions, such as Allia Bay where large areas of muddy substrate occurred, similar ingestion of algae and mud was noted.

Tilapia zillii

Most Tilapia zillii were caught over sandy or rocky substrates. Such habitats were not necessarily poor in phytoplankton, particularly in more northerly areas of the lake. Even under circumstances where the phytoplankton provided adequate food, T. zillii fed predominantly by grazing firm substrates. Where the algal community grew attached to sand grains or macrophytes, these substrates were also ingested, to an extent that they formed the major component of the gut contents

(Table 11.63). Any invertebrates inhabiting the mats formed by these algal communities were also ingested and broken down.

SUMMARY

The feeding activity of Sarotherodon niloticus was investigated by analysis of gut contents from fish caught at various localities, mostly during 1974 and 1975. Investigations over 24 hour periods showed that all size classes clearly followed a daytime feeding cycle. Fry infrequently ingested invertebrates during the hours of darkness, and adults involved in breeding or brooding fed very little.

All size classes are primarily phytophagous, grazing on the dense algal plankton found in sheltered, inshore waters. Little selectivity of food items was recorded.

Quantitative estimates of material ingested over single feeding-cycles were made as dry weights of food in the gut. The relationship between wet weight of fish and dry weight of food ingested per day is described by the equaion: Food = 0.013 x fish weight - 0.31 (all in grammes). These results are in close agreement with those from Sarotherodon niloticus in Lake George (Uganda).

Digestion of algal material, in this case mainly blue-green algae, was followed through the gut over single feeding-cyles and related to pH.

Brief notes on the food and feeding habits of Sarotherodon galilaeus and Tilapia zillii are also given

REFERENCES

BAYLEY, P B (1976). Changes in fish species composition of the yields and the development of the fishery of Lake Rudolf, Kenya. Archiv. fur Hydrobiol. 79 : 111-132.

BOWEN, S H (1976). Mechanism for digestion of detrital bacteria by the cichlid fish Sarotherodon mossambicus (Peters). Nature, Lond. 260 : 137-138.

COULTER, G W (1977). Approaches to estimating fish biomass and potential yield in Lake Tanganyika. J. Fish. Biol. 11 : 393-408.

EGGERS, D M (1977). Factors in interpreting data obtained by diel sampling of fish stomachs. J. Fish. Res. Board Can. 34 : 290-294.

FRYER, G and ILES, T D (1972). The cichlid fishes of the Great Lakes of Africa. Oliver and Boyd, Edinburgh. 641 pp.

HARBOTT, B J (1975). Preliminary observations on the feeding of Tilapia nilotica Linn. in Lake Rudolf. Afr. J. Trop. Hydrobiol. Fish. 4 : 27-37.

HENDERSON, H F and WELCOMME, R L (1974). The relationship of yield to morphoedaphic index and numbers of fishermen in African inland fisheries. CIFA Occasional paper No1. FAO, Rome : 1-19.

JENKINS, B W and GREEN, J M (1977). A critique of field methodology for determining fish feeding periodicity. Env. Biol. Fish 1 : 209-214.

JOHNSON, R P (1974). Synopsis of biological data on Sarotherodon galilaeus. FAO Fisheries synopsis No90. FAO, Rome.

LAUZANNE, L (1976). Regimes alimentaires et relations trophiques des poissons due Lac Tchad. Cah. O.R.S.T.O.M. ser. Hydrobiol. 10 : 267-310.

LELEK, A (1972). Fish populations of Kainji Lake, trends in their development and utilisation. Kainji Lake Research Project. FAO, Rome, FI : SF/NIR 24 Tech. Rep. 2 : 121p.

LOWE-McCONNELL, R H (1958). Observations on the biology of Tilapia nilotica Linne in East African waters. Rev. Zool. Bot. Afr. 57 : 129-170.

MELACK, J M (1976). Primary productivity and fish yields in Tropical lakes. Trans. Am. Fish. Soc. 105 : 575-580.

MORIARTY, C M (1973). Feeding of herbivorous fish in Lake George, Uganda. MPhil Thesis, University of Nottingham.

MORIARTY, D J W (1973). The physiology of digestion of blue-green algae by the cichlid fish, Tilapia nilotica. J. Zool. Lond. 171 : 25-40.

PETR, T (1967). Food preferences of the commercial fishes of the Volta Lake. Tech. Rep. Volta Basin Res. Proj. Univ. Ghana. (X22). 7pp

PREJS, A and BLASZCZYK, M (1977). Relationships between food and cellulase activity in freshwater fishes. J. Fish. Biol. 11 : 447-452.

RYDER, R A (1965). A method for estimating the potential fish production of north-temperate lakes. Trans. Am. Fish. Soc. 94 : 214-218.

RYDER, R A, KERR, S R, LOFTUS, K H and REGIER, H A (1974). The morphoedaphic index, a fish yield estimator - Review and evaluation. J. Fish. Res. Board Can. 31 : 663-688.

TREWAVAS, E (1933). Scientific results of the Cambridge Expedition to the East African Lakes, 1930-31. 11. The Cichlid Fishes. J. Linn. Soc. Lond (Zool). 38 : 309-341.

WELCOMME, R L (1964). The habitats and habitat preferences of the young of the Lake Victoria *Tilapia* (Pisces - Cichlidae). Rev. Zool. Bot. afr. 70 : 1-28.

THE BIOLOGY OF Haplochromis macconneli Greenwood IN LAKE TURKANA

J T N Ogari

INTRODUCTION

MATERIAL

MESH SELECTIVITY OF THE BOTTOM TRAWL

DISTRIBUTION

GROWTH

BREEDING

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REFERENCES

INTRODUCTION

Haplochromis macconneli is an endemic cichlid, common throughout the deeper waters of Lake Turkana. With a maximum recorded size of 130 mm TL the species is not likely to become commercially valuable. However, H. macconneli is an important constituent of the demersal fauna of the offshore waters where it occurs in association with Bagrus bayad and Barbus turkanae. The present study covers the period May 1972, when the species was first discovered (GREENWOOD, 1974) to October 1975.

MATERIAL

Nearly all H. macconneli examined during the present studies were caught by bottom trawling. Regular monthly samples were made in an area up to 10 km north to north-west of Central Island at depths of from 30 to 85 m. Limited material was also obtained from midwater trawl, frame trawl and metre townet hauls. Haplochromis macconneli taken in routine trawl catches were measured on board ship to the nearest cm TL below. Samples intended for detailed biological studies were either frozen or preserved in formalin, and subsequently examined in the laboratory where measurements of TL were made to the nearest mm below. A remarkable feature of the samples was the almost complete absence of males. Only two males were observed in the total of 3659 which were sexed.

MESH SELECTIVITY OF THE BOTTOM TRAWL

The bottom trawl was fitted with a cod end of 38 mm stretched mesh. A limited number of samples were made with a bag of 19 mm stretched mesh fitted over the cod end. A comparison of length frequencies of fish caught in the cod end and in the attached bag is presented in Table 11.64. The results indicate a 50% retention length of approximately 60 mm TL in the 38 mm cod end. The percentage of fish withheld by the main cod end increased throughout the recorded size range and 100% retention was achieved only in the largest fish of 110 mm TL. It is clear that the routine 38 mm bottom trawl samples on which the present study is based were non-random and strongly biased towards larger individuals. Figure 11.45 shows the length frequencies of H. macconneli in two hauls made consecutively on the same fishing grounds, the first using abottom trawl with a 38 mm cod end, the second using a midwater trawl fishing on the bottom with a 19 mm cod end. The failure of the 38 mm net to sample smaller fish is obvious.

DISTRIBUTION

Haplochromis macconneli is restricted to the offshore waters of Lake Turkana. No individuals were recorded during the extensive programme of shore sampling, and the species was completely absent from trawl and metre townet samples made in water less than 8 metres deep.

The occurrence in bottom trawl hauls is illustrated by distribution charts (Fig. 8.17 a-c). The bottom trawl data are summarised in Table 11.65 where the percentage of hauls containing H. macconneli has been calculated for each depth zone. The results shown in column 4 (Table 11.65) prove that there is a gradual increase in the frequency of occurrence of this species with depth from only 7% of hauls in the 5-10 m zone to all hauls below the 80 m contour. The pattern of distribution is similar to that of Bagrus bayad (see page 1023) which also reaches a peak of abundance in the deepest waters of the lake.

Seasonal changes in distribution are suggested by the charts (Fig. 8.17 a-c) with fish tending to move close inshore during the flood season. These trends are confirmed by results presented in Table 11.65 which show that after the flood season, during which H. macconneli was recorded from the 5-10 m depth zone, there was a progressive movement offshore. This continued through the post-flood season to the pre-flood season when the species was confined to water deeper than 15 m. It seems likely that the limit to which H. macconneli ranges inshore is restricted by a critically high level of light intensity. The offshore movement illustrated by Table 11.65 is probably correlated with increases in lake transparency, resulting in increased light penetration, following a period of relatively high turbidity during the flood season. Similar seasonal movements have been noted in other species including Barbus bynni, Bagrus bayad and Lates longispinis during the present project.

Haplochromis macconneli appears to be almost entirely demersal in distribution and was recorded only rarely in midwater trawl, frame trawl and metre townet catches made away from the bottom.

Diel changes in the vertical distribution of openwater fish were investigated with a series of both frame trawl and metre townet hauls during the courses of the present project. The frame trawl results show that unlike most species concerned, H. macconneli showed no tendency to migrate upwards from the bottom at night (Fig. 8.35).

Variations in the length frequency distribution of H. macconneli with depth have been investigated. Differences were often noted within a particular series of samples but no consistent trends were detected. For example, in the Longech-Central Island area the proportion of smaller fish decreased markedly with depth on 20th August 1973 at three stations, ranging from 32 m to 60 m in lake depth (Fig. 11.46a) whereas on 25th September 1972 a tendency for the proportion of smaller fish to increase in depth is evident (Fig. 11.46b). On other occasions virtually identical length frequency distributions were obtained from samples differing widely in depth (Fig. 11.46c).

GROWTH

An accurate assessment of growth in H. macconneli has not proved possible due to the non-random nature of the samples (see above). However, monthly length frequency histograms which were constructed from bottom trawl data combined from all areas of the lake have provided limited information on recruitment and growth. A regular annual pattern is discernable in the histograms (Fig. 11.47). Modal lengths were at a seasonal maximum of over 75 mm TL during August and September in both 1972 and 1973. In each year the peak period was followed during October and November by a marked fall in modal length which was accompanied by a sharp decrease in the proportion of fish above 70 mm TL and a corresponding increase in fish below 50 mm TL. During succeeding months a steady increase in size is evident from the histograms, particularly during the period December 1972 to May 1973 for which a complete set of observations is available.

It seems probable from these results that mature fish of ca 60-90 mm TL, all belonging to the same age class, suffer heavy mortality between September and October each year. As a consequence they are replaced as the dominant group of mature fish by individuals from a younger age class. Limited data from catches with the 19 mm bag attached to the cod end provide more accurate information on the true size structure of the population. Thus in August 1973 (Fig. 11.46a) results indicate that two main size classes were present with modal lengths of 35 and 75-80 mm respectively. It seems reasonable, in view of the annual pattern of recruitment shown by Figure 11.47, to assume that spawning was restricted to a limited period each year. Under such circumstances, the two main size groups in Figure 11.46a represent year classes, the smaller 0-group fish of the 1972 year class and the larger 1-group fish of the 1971 year class. In a discussion on breeding in H. macconneli (see below) it is suggested that the peak spawning period occurs during October, at the time of the late flood season. If this is correct, the two size groups in Figure 11.45a are approximately 10 and 22 months old respectively, suggesting that for the first two years of life H. macconneli grows at a rate of approximately 35-40 mm per year.

While the present observations indicate that most fish do not survive beyond an age of two years, the presence of exceptional individuals up to a maximum size of 130 mm indicates that certain fish live to a greater age of perhaps 3 or 4 years.

BREEDING

The dearth of males in samples of H. macconneli has been noted above. Only two males were identified out of a total of 1214 fish ranging from 26 to 113 mm TL which were examined gonadially. The males of 31.0 mm and 35.5 mm TL were caught by bottom trawl at a depth of 30 m in the open lake 2.4 km east of North Island. Both were sexually adult and one was in an advanced stage of ripening. The smallest ripe (stage V) female was 50 mm TL suggesting marked sexual dimorphism in adult size. Smaller size groups were poorly represented in the samples due to escapement from the 38 mm cod end and the paucity of males is possibly the result of non-random sampling.

The maturity of ovaries was classified according to the following schedule:

Stage I	immature
Stage II	virgin resting
Stage III	early maturing
Stage IV	late maturing
Stage V	ripe

After spawning, ovaries reverted to Stage III in which small but recognisable oocytes were present.

The left ovary of H. macconneli was often non-functional. The following conformations were noted out of a total of 40 females of 60 mm TL and above:

(i)	Right ovary alone developed	- 24 fish
(ii)	Right ovary fully developed, left ovary only partially developed	- 14 fish
(iii)	Both ovaries fully developed	- 2 fish

All data relating to the size at maturity in female H. macconneli have been combined in Table 11.66 to provide an estimate of the size at which the species spawns for the first time. The results indicate that females initially ripen at a mean length of about 54 mm at an age 15 to 18 months.

Seasonal changes in the pattern of length frequency histograms of H. macconneli (Fig. 11.47) suggest that a period of peak spawning activity occurs regularly each year. Gonadial data (Table 11.67) prove that ripe females are present throughout the year but that the proportion rises to a peak in October. This corresponds with the period when heavy mortality is apparent in the larger fish (see above). Such mortality may have followed spawning and brooding.

Conditions are very stable in the benthic environment of H. macconneli with an annual temperature range of only 1 C from 25 to 26 C in deeper offshore waters (see page 36). The main environmental change in the openwaters is the regular annual influx of turbid Omo flood water which affects most of the northern basin of the lake between July and September each year. Breeding in H. macconneli may be controlled by this factor.

Very little evidence is available on the occurrence of brooding fish. No mouth broods were observed in trawled samples, presumably due to the shedding of young by females during lengthy net hauling. Yolk-sac larvae of 6-7 mm TL occurred at only 2 out of 219 oblique metre townet samples (Table 11.68).

The 109 larvae at stations 397/24 probably originated from a female of 80 mm TL caught in the same haul. These isolated observations indicate that the spawning involves no migration to special nursery grounds but occurs in the open lake, in the deeper water regions normally inhabited by this species.

The fecundity of H. macconneli is illustrated in Figure 11.48 where the number of ova from a total of 47 fish has been plotted against length. Individual counts ranged from 21 eggs in a fish of 74 mm with a single ovary to 226 eggs in a fish of 98 mm which had a partially developed left ovary in addition to the normal right ovary.

FOOD

The stomach contents of 47 Haplochromis macconneli were examined during the present investigations. A volumetric method (HYNES, 1950) was used in the analysis of food. The fullness of a stomach was judged subjectively on a 10 point scale: 0 - empty to 10 - full. The contribution made by each food item was then assessed as a percentage of the total food present. Finally a number of points was awarded to each food item by multiplying fullness by percentage contribution and dividing by 10.

The results are analysed in Table 11.69. Prawns were the most important food item forming nearly 80% of the total volume. Most of the prawns were unidentifiable due to mastication and digestion but both Macrobrachium and Caridina were recorded. Fish were of minor importance forming 16% of the food. Barbus annamensis and Haplochromis were the two forms identified. It seems likely that H. macconneli is cannibalistic since of the other two Haplochromis recorded from the lake H. rudolfianus is littoral in distribution and H. turkanae has been noted only rarely. Other food items apart from prawn and fish occurred only rarely. The results prove that H. macconneli is a predatory form feeding on or near the bottom in deeper water where adult prawns of both species are common. Haplochromis macconneli is in turn regularly preyed on by Bagrus bayad (see page 1036).

SUMMARY

Haplochromis macconneli is a demersal species confined to the offshore waters of Lake Turkana below the 10-15 m contours and becoming increasingly common with depth. Slight seasonal movements were detected with the species tending to occur closer inshore during the flood season when turbidity increases. Diel vertical migrations were not observed in H. macconneli.

Petersen's method of length frequency analysis suggested that a growth rate of ca 35-40 mm per year is maintained for the first two years of life. Sexual maturity in females is attained at about 54 mm TL at an age of 15-18 months. The proportion of fish surviving into their third year is low but individuals approaching the maximum size of 130 mm TL may be up to 4 years old.

There was an overwhelming preponderance of females in the material examined and only two males (of 31 and 35 mm TL) were found in a total of 1214 fish. Both males were sexually mature suggesting sexual dimorphism in size. Spawning probably occurs throughout the year but peak activity was noted during the Omo flood season.

The food consists chiefly of prawns with a smaller proportion of fish and benthic forms including insects and molluscs.

REFERENCES

GREENWOOD, P h (1974). The *Haplochromis* species (Pisces: Cichlidae) of Lake Rudolf, East Africa. *Bull. Brit. Mus. nat. Hist.(Zool).* *27* : 139-165.

HYNES, H B N (1950). The food of freshwater sticklebacks (*Gasterosteus aculeatus* and *Pygosteus pungitius*), with a review of methods used in studies of the food of fishes. *J. Anim. Ecol.* *29* : 36-58.

TABLE 11.1

Wet weight of Lates niloticus in tonnes purchased by the Turkana Fishermen's Co-operative at various branches on the west shore of the lake during two 12 month periods. The weight expressed as a percentage of the total catch is shown in brackets.

Station	Nov 72 - Oct 73	Nov 73 - Oct 74
Kerio	113.5 (25)	115.0 (28)
Eliye	39.4 (36)	40.0 (36)
Kalokol	21.4 (14)	108.2 (37)
Namudak	5.5 (7)	11.7 (14)
Kataboi	8.3 (5)	15.9 (9)
Nachukui	24.3 (12)	22.4 (12)
Lowarangak	33.2 (12)	34.2 (11)
Todenyang	102.6 (14)	122.7 (15)
Total	348.2 (16)	470.1 (20)

TABLE 11.2

Showing estimates of length for age in the Lake Turkana population of *Lates niloticus*, based on direct observations made at Lake Chad (see text). Weights have been derived from the relationship $w(gm) = 0.0065\ l^{3.14}$

Age (years)	Total length (cm)	Weight kg
1	28.6	0.25
2	51.7	1.60
3	69.4	4.02
4	82.8	6.98
5	93.0	10.03
6	105.4	14.83
7	115.7	19.86
8	126.1	25.99
9	136.5	33.29
10	146.8	41.78
11	157.2	51.75
12	167.6	63.22
13	177.9	76.17
14	188.3	90.97
15	198.6	107.74

TABLE 11.3

Showing changes in the mean value of K, the condition factor, with size in male and female *Lates niloticus*.

Length class (cm T.L.)	Males		Females	
	No	$\bar{K}$	No	K
30	6	1.02	6	1.05
40	27	1.13	15	1.12
50	35	1.18	13	1.18
60	19	1.16	9	1.16
70	54	1.26	16	1.17
80	80	1.27	8	1.22
90	39	1.29	11	1.25
100	13	1.26	9	1.24
110	6	1.30	19	1.29
120	4	1.31	19	1.30
130	0	-	20	1.44
140	1	1.24	16	1.37
150			3	1.37
160			3	1.36
170			7	1.42
180			1	1.51

TABLE 11.4

Changes in the maturity of male *Lates niloticus* with size. Showing the percentage of fish at various stages of maturity in each length group. All data from experimental nets for the period June 1972 to October 1974 have been combined with supplementary records from the Longech Angling Lodge.

Length group (TL in cm)	Stages 2 and 3	Stage 4	Stages 5 and 6	Stages 4,5 and 6	Number of fish
20-25	100	-	-	-	2
25-30	100	-	-	-	8
30-35	100	-	-	-	29
35-40	100	-	-	-	29
40-45	100	-	-	-	43
45-50	98	2	-	2	44
50-55	90	10	-	10	59
55-60	80	16	4	20	56
60-65	61	25	14	39	64
65-70	46	38	15	53	60
70-75	40	32	28	60	90
75-80	18	30	53	83	101
80-85	25	25	50	75	122
85-90	17	25	57	82	91
90-95	11	25	63	88	63
95-100	12	35	53	88	34
100-105	24	21	56	77	34
105-110	19	19	63	82	16
110-120	19	19	63	82	27
120-130	-	44	56	100	9
130-140	-	-	100	100	1
over 140	-	100	-	100	1
				Total number	983

TABLE 11.5

Changes in the maturity of female *Lates niloticus* with size. Showing the percentage of fish at various stages of maturity in each length group. All data from experimental nets for the period June 1972 to October 1974 have been combined with supplementary records from the Longech Angling Lodge.

Length group (TL in cm)	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7	Number of fish
20-25	100	-	-	-	-	-	1
25-30	100	-	-	-	-	-	4
30-35	100	-	-	-	-	-	15
35-40	100	-	-	-	-	-	27
40-45	100	-	-	-	-	-	38
45-50	100	-	-	-	-	-	36
50-55	100	-	-	-	-	-	37
55-60	100	-	-	-	-	-	34
60-65	100	-	-	-	-	-	40
65-70	95	5	-	-	-	-	55
70-75	94	6	-	-	-	-	63
75-80	93	5	1	-	-	-	75
80-85	86	9	2	3	-	-	66
85-90	80	11	1	7	-	-	70
90-95	78	13	2	7	-	-	86
95-100	71	11	14	5	-	-	66
100-105	77	14	3	5	2	-	64
105-110	73	9	7	11	-	-	45
110-120	65	11	17	6	1	-	77
120-130	53	10	17	19	2	1	60
130-140	50	7	19	19	5	-	42
over 140	53	5	22	20	-	-	74
Total number							1070

TABLE 11.6

Showing seasonal variations in the maturity of male *Lates niloticus* of 70cm T.L. and over. Data from June 1972 to October 1974 have been combined and the numbers in each category are expressed as a percentage of the monthly total.

Month	Stages 2 and 3	Stage 4	Stages 5 and 6	Total numbers
Jan	11	39	50	18
Feb	34	27	39	44
Mar	48	17	34	29
Apr	71	17	12	41
May	20	22	39	33
Jun	41	22	38	32
Jul	15	23	60	98
Aug	16	32	52	44
Sep	8	24	68	112
Oct	9	33	58	43
Nov	15	30	56	27
Dec	25	30	46	57

TABLE 11.7

Showing seasonal variations in the maturity of female *Lates niloticus* of 90cm T.L. and over. Data from June 1972 to October 1974 have been combined and the numbers in each category are expressed as a percentage of the monthly total.

Month	Stages 2 and 3	Stage 4	Stages 5 and 6	Total numbers
Jan	79	7	14	29
Feb	68	21	11	71
Mar	75	13	11	53
Apr	78	12	10	49
May	76	10	14	29
Jun	74	5	21	43
Jul	78	17	9	54
Aug	62	15	23	26
Sep	59	27	14	49
Oct	77	19	3	31
Nov	90	10	-	40
Dec	77	5	18	39

TABLE 11.8

Showing changes in sex ratio of Lates niloticus with length for a) all trawl-caught fish during the period May 1972 - October 1974 and b) fish caught by angling at the Longech Angling Lodge between February 1973 and July 1974. The sex ratio is expressed as the number of females per 100 males. Ratios which are not significantly different from 100 (chi squared = < 3.841) are marked with an asterisk.

Length group T.L. in cm	Trawled fish all localities			Longech Angling Lodge data		
	No. females	No. males	Sex ratio	No. females	No. males	Sex ratio
20	3	3	100*	-	-	
30	25	32	78*	-	-	
40	33	46	72*	2	3	67*
50	41	70	59	9	6	150*
60	53	56	95*	14	21	67*
70	53	94	56	47	30	157*
80	52	116	45	56	22	255
90	42	44	95*	95	19	500
100	18	23	78*	84	20	420
110	28	9	311	43	18	239
120	21	4	525	33	4	825
130	21	1	2100	21	2	1050
140	18	1	1800	19	-	∞
150	5	-	∞	15	-	∞
160	4	-	∞	8	-	∞
170	7	-	∞	3	-	∞
180	1	-		-	-	
Total	425	499		499	145	

TABLE 11.9

Lates niloticus : an analysis of the food of 1100 fish examined on board R.V. HALCYON, from all localities, between May 1972 and November 1974. The method of capture was chiefly bottom trawl. The number of points scored by each food item in a particular size group is expressed as a percentage of the total points for all items in that size group.

Size range (in cm)	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100-109	110-119	120-189	All sizes
Total examined	58	85	125	126	200	221	109	55	40	81	1100
No. stomachs *in situ*	58	84	109	108	181	186	94	50	28	47	945
% everted stomachs	-	1	13	14	9	16	14	10	30	34	14
% empty stomachs	52	38	27	36	57	55	56	52	59	51	48
No. with food	28	52	74	69	77	84	41	24	11	22	490
Food items :-											
Caridea	-	1	+	-	-	-	-	-	-	-	+
Anisopteran larvae	5	2	+	-	+	-	-	-	-	-	+
Hydrocynus forskalii	-	5	2	4	1	1	8	14	-	7	4
Alestes ferox	-	8	3	8	13	5	-	10	-	+	6
A. minutus	-	-	-	-	-	+	-	-	-	-	+
A. baremose	-	-	-	-	-	2	-	-	-	-	+
Citharinus citharus	-	-	-	-	-	-	-	-	-	8	+
Labeo horie	-	-	2	-	+	-	-	-	-	-	+
Barbus bynni	-	-	1	2	2	+	-	-	-	-	1
Schilbe uranoscopus	2	-	-	1	-	2	9	-	3	-	2
Chrysichthys auratus	-	3	15	15	8	4	2	2	-	2	7
Bagrus bayad	-	-	11	3	11	18	19	20	30	11	11
Clarias lazera	-	-	-	-	-	-	-	-	-	+	+
Synodontis schall	4	-	-	-	2	-	-	-	-	2	+
Lates niloticus	-	-	-	-	-	3	4	-	-	-	1
L. longispinis	6	4	9	7	9	18	5	16	14	12	10
Sarotherodon spp.	9	37	23	41	41	28	29	23	36	25	31
Haplochromis spp.	-	-	2	-	-	-	1	-	-	-	+
All cichlids *	45	41	35	44	41	30	30	23	36	25	36
Unidentified fish	36	36	21	13	10	15	17	13	13	5	17
All fish	95	97	99	100	99	100	100	100	100	100	99
Anomura	-	-	-	-	+	-	-	-	-	-	+
Total points	138	249	449	418	465	478	236	140	100	186	2859
% max. possible pts	15	18	26	24	16	16	15	15	22	24	16

* including unidentified cichlids

TABLE 11.10

Showing the incidence of copepod ectoparasites on *Lates niloticus* trawled from three depth zones in the Allia Bay area.

	Depth zone		
	0-10m	10-20m	over 20m
Number of fish	198	5	30
Size range (cm T.L.)	32-184	65-146	73-130
% parasite-free	52	-	50
% with argulids	42	40	-
% with *Opistholernaea longa*	11	80	50
Number *O. longa* per fish (± SD)	1.6 (1.1)	7.8 (13.5)	27.4 (28.8)

TABLE 11.11

Showing seasonal changes in the number per standard haul and mean length of *Lates* spp. post-larvae in oblique metre townet catches at station H1 ca 2km north of Central Island during the period September 1972 to July 1974.

Date		Mean total length in mm (± S.D.)		Number per standard haul
1972:	Sep 11	11.3	(2.23)	13
	Sep 27	10.3	(2.12)	41
	Oct 30	10.2	(2.51)	3
	Nov 23	11.5	(1.55)	6
	Dec 18	10.9	(1.95)	17
1973:	Jan 11	10.4	(2.79)	20
	Jan 29	9.1	(2.62)	11
	Feb 2	10.4	(1.96)	2
	Feb 19	9.3	(2.60)	25
	Apr 26	11.5	-	1
	May 14	9.9	(2.15)	3
	Jun 14	7.0	(2.27)	8
	Jul 7	10.3	(3.20)	4
	Aug 17	7.5	-	1
	Aug 21	8.9	(1.67)	10
	Sep 26	7.3	(1.97)	50
	Nov 11	9.1	(1.34)	6
	Dec 12	9.8	(2.22)	4
1974:	Feb 24	9.5	(1.00)	5
	Mar 28	9.5	(1.51)	7
	May 13	7.5	(1.14)	35
	Jul 23	-		0

TABLE 11.12

Seasonal changes in the occurrence of early juvenile *Lates* spp. in foot seine catches at Lodge Bay, Longech Spit. Data for the period December 1972 to August 1974 have been combined on a monthly basis.

Month	No samples	Mean No *Lates* per sample	Size range (T.L. in mm) Min.	Size range (T.L. in mm) Max.	Mean length in mm (± S.D.)	
Jan	2	268	15	55	25.6	(5.59)
Feb	0	-	-	-	-	
Mar	2	17	14	44	26.5	(6.64)
Apr	2	24	16	35	23.6	(3.67)
May	3	60	15	61	25.4	(6.72)
Jun	3	49	20	54	33.1	(8.76)
Jul	2	29	16	61	36.2	(12.01)
Aug	3	17	10	52	28.1	(11.32)
Sep	1	13	19	29	25.8	(3.15)
Oct	1	45	18	57	37.7	(12.79)
Nov	1	23	14	39	21.6	(6.00)
Dec	2	41	16	61	17.7	(8.47)

TABLE 11.13

Value of percentage retention of *Lates longispinis* by a 38mm stretched mesh cod-end, compared to a 19mm stretched mesh outer retaining bag obtained from nineteen bottom trawl hauls between August and September 1973.

Total length (cm)	% retained by 38mm stretched mesh cod-end	Total number of fish
4	0	1
5	50	2
6	-	-
7	25	7
8	80	12
9	80	12
10	71	49
11	86	57
12	75	86
13	90	86
14	86	97
15	83	93
16	93	61
17	89	60
18	90	55
19	95	44
20	94	36
21	97	34
22	88	27
23	96	26
24	100	31
25	100	25
26	93	30
27	100	19
28	91	35
29	97	33

TABLE 11.14

Mean catch of Lates longispinis expressed in numbers per hour or kilograms per hour, per 5cm size class, obtained by all quantitative bottom trawl hauls in the Northern, Central and Southern Sectors, with a grand mean for the whole lake between June 1972 and August 1975. All catches are expressed as catch per unit effort for the three-gridled trawl. Weights have been calculated from the length-weight relationship for each 1cm size class obtained from L. longispinis during the same period.

Sector	Numbers per hour			
	Northern	Central	Southern	Entire Lake
Size class (T.L. cm)				
0	0.1	+	-	0.1
5	5.5	16.1	2.6	13.4
10	20.7	58.8	5.6	48.7
15	25.4	53.0	13.0	45.5
20	25.0	47.9	17.5	42.0
25	25.0	40.8	17.6	36.5
30	25.9	38.1	12.3	34.0
35	12.1	12.2	2.9	11.4
40	3.1	2.2	0.3	2.1
45	1.3	0.7	0.1	0.7
50	0.8	0.3	-	0.4
55	+	0.1	0.2	0.1
60	+	+	-	+
Total	145.0	270.5	72.0	234.9

Sector	Kilograms per hour			
	Northern	Central	Southern	Entire Lake
Size class (T.L. cm)				
0	+	+	-	+
5	+	+	+	+
10	0.4	1.2	0.1	1.0
15	1.3	2.8	0.7	2.4
20	2.7	5.2	1.9	4.6
25	4.9	8.0	3.4	7.1
30	8.2	12.0	3.9	10.7
35	5.8	5.9	1.4	5.4
40	2.1	1.5	0.2	1.5
45	1.2	0.6	0.1	0.6
50	1.0	0.4	-	0.4
55	0.1	0.2	0.3	0.2
60	+	+	-	+
Total	27.9	37.9	12.0	34.1

* See Chapter 8 for number and distribution of trawl hauls.

TABLE 11.15

The rate of evertion of all *Lates longispinis* stomachs examined from bottom trawl hauls compared with lake depth. Results have been expressed as a percentage of the total sample in 5cm size classes and 10m depth zones. Sample size is recorded in brackets.

Size class (T.L. cm)	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40+
Depth zone (m)									
0-10	-	- (1)	- (5)	- (8)	- (6)	- (11)	- (15)	- (25)	-(15)
10-20	-	- (2)	9(22)	11(85)	33(131)	21(192)	31(279)	30(105)	18(38)
20-30	-(1)	3(30)	31(71)	54(12)	45(174)	46(265)	54(368)	58(167)	84(55)
30-40	-	67 (3)	64(36)	64 (75)	54 (48)	56 (55)	71 (62)	74 (35)	83(24)
40-60	-	-	60 (5)	63 (19)	67 (21)	50 (12)	75 (16)	83 (6)	90(10)
60+	-	-	-	33 (3)	50 (4)	87 (15)	57 (14)	67 (3)	50 (4)

TABLE 11.16

Distribution of *Lates longispinis* expressed as a percentage of total catch in 5cm size classes from all Boris midwater trawl hauls made at a minimum of 7 metres above the bottom, in various lake depth zones, between September and November 1975.

Depth zone (m)	15-25	25-30	30-50	50+
Size class (T.L. cm)				
5-10	-	1	5	-
10-15	32	25	43	48
15-20	18	7	18	30
20-25	11	10	4	7
25-30	13	7	8	4
30-35	14	29	13	7
35-40	7	17	8	4
40-45	2	1	2	-
45-50	4	0	-	-
50-55	-	1	-	-
Total number of fish	56	69	195	82
Number of tows	13	13	29	26

TABLE 11.17

Distribution of *Lates longispinis* expressed as a percentage of total catch in 5cm size classes, from all Boris midwater trawl hauls made in lake depths of 30 to 50 metres between September and November 1975, and all bottom trawl hauls in 30 to 50 metres of water between September and November 1972, 1973 and 1974. Cod-end stretched mesh was 19mm in the Boris midwater trawl and 38mm in the bottom trawl.

Gear	Boris midwater trawl			Bottom trawl
Depth of tow (m)	0-11	8-19	12-24	bottom 4m
Size class (T.L. cm)				
5-10	6	2	7	-
10-15	44	33	49	25
15-20	30	5	17	40
20-25	3	9	1	11
25-30	5	16	4	5
30-35	6	24	10	6
35-40	2	12	11	8
40-45	5	-	-	2
45-50	-	-	-	1
50-55	-	-	-	+
Total number of fish	66	58	71	186
Number of tows	14	9	5	13

TABLE 11.18

Mean catch of *Lates longispinis* in all quantitative bottom trawl hauls taken in the Central Sector of Lake Turkana between June 1972 and August 1975. Catch has been expressed for immature (I), female (F) and male (M) *Lates longispinis* as mean catch in numbers per hour for the three-bridled trawl in each of five depth zones per month. Where numbers of samples were inadequate successive months have been combined. The number of tows in each depth zone are recorded in brackets.

Month	Sex	Depth range (m)				
		0-10	10-20	20-30	30-50	50+
January	I	-	41	3	-	-
	F	+	214	19	3	-
	M	+	223	20	-	-
(No of tows)		(4)	(7)	(1)	(1)	(3)
February	I	-	120	192	-	41
	F	-	71	396	-	69
	M	-	83	487	-	82
(No of tows)		(2)	(1)	(8)	(1)	(3)
March + April	I	-	389	102	15	+
	F	2	335	278	12	+
	M	+	205	337	1	-
(No of tows)		(2)	(2)	(3)	(2)	(5)
May	I	+	120	1	10	3
	F	5	282	11	9	1
	M	1	103	56	7	-
(No of tows)		(3)	(4)	(2)	(7)	(8)
June	I	-	288	70	257	2
	F	-	72	20	535	2
	M	-	34	37	448	1
(No of tows)		(3)	(2)	(4)	(3)	(4)
July	I	1	31	-	146	-
	F	7	98	83	116	1
	M	6	60	83	109	-
(No of tows)		(6)	(6)	(4)	(4)	(9)
August	I	-	45	88	72	-
	F	-	57	57	87	-
	M	-	48	102	22	-
(No of tows)		(2)	(5)	(4)	(9)	(4)
September	I	14	196	66	26	3
	F	10	110	21	4	2
	M	4	205	10	2	1
(No of tows)		(9)	(6)	(4)	(4)	(4)
October	I	-	135	127	-	1
	F	6	40	42	-	1
	M	2	22	22	-	+
(No of tows)		(1)	(2)	(6)	(1)	(8)
November + December	I	37	27	48	2	1
	F	118	48	94	10	23
	M	53	22	33	8	9
(No of tows)		(10)	(6)	(9)	(8)	(5)

TABLE 11.19

The mean retention length (T.L. in cm) for all *Lates longispinis* caught in all experimental multifilament nylon gillnets of various mesh sizes employed between November 1972 and August 1975.

Stretched mesh (inches)	2	2.5	2.88	3.5	4	4.33	5	6	7	8	9
Mean retention length (cm)	25.5	27.8	31.45	35.5	35.5	36.3	39.5	32.65	28.0	29.5	35.5
Number of fish	564	31	289	17	112	193	25	13	6	2	1
Standard deviation (cm)	4.67	7.17	4.34	5.73	8.79	9.82	10.28	13.95	12.08	-	-

TABLE 11.20

Values assigned to the medians of the modes shown in the length frequency distributions of Lates longispinis sampled by bottom trawling in the Ferguson's Gulf area between June 1972 and August 1974. The year classes which it is considered that the various cohorts belonged to is indicated below.

Month number	Month	Median of mode (cm)					Mean of modes (cm)
1	Dec	-	-	1.5	-	6.5	4.0
2	Jan	-	-	5.0	-	-	5.0
3	-	-	-	10.5	7.0	-	8.8
4	-	-	-	11.5	10.5	-	11.0
5	-	-	-	11.0	12.0	-	11.5
6	-	-	-	12.5	18.5	12.0	14.3
7	Jun	-	-	17.0	-	13.0	15.0
8	Jul	-	-	15.0	-	-	15.0
9	-	-	16.0	14.0	12.5	14.0	14.1
10	-	-	16.5	15.5	13.5	-	15.2
11	-	-	17.5	16.5	-	-	17.0
12	-	-	21.0	19.0	-	-	20.0
13	Dec	-	21.5	21.5	20.0	-	21.0
14	Jan	-	22.5	22.0	-	-	22.3
15	-	-	21.8	21.0	-	-	21.4
16	-	-	23.7	22.5	-	-	23.1
17	-	-	-	23.5	-	-	23.5
18	-	-	-	28.5	24.0	-	26.3
19	Jun	31.0	29.0	-	26.0	-	28.7
20	Jul	31.5	29.0	-	-	-	30.3
21	-	32.5	31.0	-	27.5	-	30.3
22	-	33.5	31.0	-	-	-	32.3
Year class		1970-71	1971-72	1972-73	1973-74	1974-75	

TABLE 11.21

The relationship between length and weight in all *Lates longispinis* examined between June 1972 and February 1975 represented by the formula

$$\log w = \log u + v \log l$$

where w in weight in grams, l total length in cm, u and v constants in the geometric mean functional linear regression, and r^2 the correlation coefficient.

L. longispinis	u	v	r^2	Number examined
Immature	0.0166	2.81	0.98	698
Female	0.0103	2.97	0.97	1109
Male	0.0119	2.93	0.97	818
Unsexed	0.0136	2.89	0.99	261
Total sample	0.0140	2.88	0.99	2886

TABLE 11.22

The mean value of condition factor ($\bar{k}$) for all *Lates longispinis* examined between July 1972 and February 1975, in 5cm size classes in each sex, together with the number examined.

K has been derived from the relationship $k = \frac{100w}{l^3}$ where w = weight in gm and l = total length in cm.

Length class (cm T.L.)	Immature		Female		Male		Unsexed		Total sample	
	$\bar{k}$	No	$\bar{k}$	No	$\bar{k}$	No	$\bar{k}$	No	$\bar{k}$	No
0	1.27	9	-	-	-	-	-	-	1.27	9
5	1.12	120	-	-	-	-	-	-	1.12	120
10	1.03	278	-	-	1.07	1	1.16	1	1.03	280
15	0.98	242	0.97	65	0.95	49	1.01	19	0.97	375
20	0.96	41	0.95	343	0.95	223	0.97	38	0.95	645
25	1.10	1	0.94	266	0.94	220	0.95	37	0.94	524
30	-	-	0.93	282	0.94	240	0.94	101	0.94	623
35	-	-	0.93	105	0.91	71	0.90	47	0.92	223
40	-	-	0.93	26	0.96	9	0.95	9	0.94	44
45	-	-	0.91	11	1.11	1	0.90	4	0.92	16
50	-	-	0.94	4	1.17	1	0.93	2	0.97	7
55	-	-	0.95	1	-	-	-	-	0.95	1
60	-	-	-	-	-	-	0.99	1	0.99	1

TABLE 11.23

Changes in the maturity of female *Lates longispinis* with size. Showing the percentage of fish at various stages of maturity in each length group for all females caught in experimental trawl nets during the period June 1972 to November 1974. Total number of fish examined : 5810.

Length group (T.L. in cm)	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7	Number of fish
13-14	100	-	-	-	-	-	1
14-15	100	-	-	-	-	-	1
15-16	100	-	-	-	-	-	9
16-17	100	-	-	-	-	-	25
17-18	97	3	-	-	-	-	36
18-19	100	-	-	-	-	-	114
19-20	100	-	-	-	-	-	225
20-21	100	+	-	-	-	-	294
21-22	99	+	1	-	-	-	334
22-23	98	1	1	-	-	-	350
23-24	95	2	2	1	-	-	263
24-25	95	2	2	+	-	-	284
25-26	90	7	3	+	+	-	268
26-27	87	4	8	+	-	-	252
27-28	68	17	13	2	-	-	278
28-29	68	10	16	6	-	-	281
29-30	56	15	20	10	1	-	323
30-31	43	16	28	12	-	+	337
31-32	32	15	33	20	1	-	320
32-33	27	18	30	25	1	-	299
33-34	25	14	28	33	-	-	265
34-35	20	15	34	31	+	-	247
35-36	18	14	36	29	2	1	212
36-37	20	17	37	25	2	1	178
37-38	15	18	33	33	3	-	120
38-39	17	21	30	30	2	-	105
39-40	17	24	33	24	1	-	75
40-41	33	15	23	27	-	2	60
41-42	31	2	21	36	-	-	42
42-43	27	18	33	20	2	-	45
43-44	32	21	25	21	-	-	28
44-45	36	14	32	18	-	-	22
45-46	18	23	32	22	-	-	22
46-47	38	6	31	25	-	-	16
47-48	40	7	47	7	-	-	15
48-49	50	25	17	8	-	-	12
49-50	22	22	22	22	11	-	9
50-55	42	21	24	12	-	-	33
Over 55	45	-	45	9	-	-	11

TABLE 11.24

Changes in the maturity of male Lates longispinis with size. Showing the percentage of fish at various stages of maturity in each length group for all males caught in experimental trawl nets during the period June 1972 to November 1974. Total number of fish examined : 4253.

Length group (T.L. in cm)	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7	Number of fish
13-14	100	-	-	-	-	-	1
14-15	100	-	-	-	-	-	3
15-16	100	-	-	-	-	-	8
16-17	100	-	-	-	-	-	14
17-18	100	-	-	-	-	-	47
18-19	99	1	-	-	-	-	93
19-20	91	7	2	-	-	-	138
20-21	84	14	2	-	-	-	188
21-22	69	26	4	+	-	-	211
22-23	60	32	8	-	-	-	229
23-24	41	40	17	1	-	-	206
24-25	30	39	27	4	-	-	187
25-26	30	27	37	7	-	-	177
26-27	18	32	40	10	-	-	240
27-28	13	29	47	11	-	-	218
28-29	6	28	48	18	-	-	280
29-30	7	18	52	23	+	-	274
30-31	6	12	50	31	1	-	286
31-32	6	10	52	30	1	-	299
32-33	4	6	51	37	1	1	279
33-34	7	9	53	31	-	1	198
34-35	6	5	46	42	1	-	202
35-36	6	4	43	44	3	1	136
36-37	6	7	50	35	2	-	105
37-38	8	5	54	34	-	-	65
38-39	11	9	33	47	-	-	55
39-40	3	8	47	39	3	-	38
40-42	14	7	34	45	-	-	29
42-44	67	8	25	-	-	-	12
44-46	30	30	30	10	-	-	10
46-48	25	25	-	25	-	25	4
48-50	40	40	-	20	-	-	5
50-55	50	10	20	20	-	-	10
over 55	50	17	33	-	-	-	6

TABLE 11.25

Changes in the percentage of Stage 2 to Stage 4 female *Lates longispinis* with evident corpora lutea or residual eggs in length groups for fish sampled between June 1972 and November 1975.

Length group (T.L. in cm)	Corpora lutea or yolk sacs evident	Number of fish
13-26	-	2204
26-27	-	252
27-28	-	278
28-29	1	281
29-30	1	323
30-31	1	337
31-32	4	320
32-33	6	299
33-34	7	265
34-35	5	247
35-36	8	212
36-37	15	178
37-38	11	120
38-39	14	105
39-40	17	75
40-41	33	60
41-42	21	42
42-43	24	45
43-44	29	28
44-45	41	22
45-46	23	22
46-47	31	16
47-48	33	15
48-49	58	12
49-50	44	9
50-55	39	33
over 55	0	11

TABLE 11.26

Seasonal variation in the maturity of female Lates longispinis of 30cm T.L. and over. Data from all trawl hauls between June 1972 and November 1975 have been combined. The numbers of females of maturity Stage 2 to Stage 7 and females in which corpora lutea or residual eggs are evident have both been expressed as a percentage of the monthly total.

Month	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7	Corpora lutea or yolk sacs evident	Total numbers
Jan	4	13	26	56	1	-	2	82
Feb	11	10	25	50	3	1	11	195
Mar	16	14	28	40	-	1	7	166
Apr	53	16	16	15	+	+	17	301
May	53	9	21	18	-	1	6	194
Jun	32	18	25	23	1	-	5	197
Jul	31	22	32	14	1	-	5	154
Aug	23	16	36	25	1	-	4	273
Sep	19	19	43	19	-	-	6	227
Oct	20	21	39	19	+	+	9	214
Nov	31	19	38	11	+	-	11	232
Dec	12	14	42	32	-	-	7	251

TABLE 11.27

Seasonal variation in the maturity of male *Lates longispinis* of 30cm T.L. and over. Data from all trawl hauls between June 1972 and November 1975 have been combined and the numbers in each category have been expressed as a percentage of the monthly total.

Month	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7	Total numbers
Jan	2	4	35	59	-	-	99
Feb	1	3	46	49	1	1	349
Mar	1	7	51	38	2	1	166
Apr	16	17	52	15	-	-	159
May	3	13	43	37	-	4	95
Jun	5	6	46	44	-	-	162
Jul	28	10	41	22	-	-	125
Aug	1	6	54	38	-	1	145
Sep	5	10	58	21	4	1	183
Oct	3	19	43	34	-	-	99
Nov	21	9	51	18	-	-	98
Dec	10	13	44	32	2	-	63

TABLE 11.28

Showing the changes in the sex ration with length for all Lates longispinis caught by bottom trawling in four depth zones within the Northern, Central and Southern Sectors of Lake Turkana, during the period June 1972 to August 1975. Sex ratio is expressed as numbers of females per 100 males in each length group. Ratios which are not significantly different from 100 (chi - squared < 3.841) are marked with an asterisk. Ratios in samples of less than 5 fish of one sex are omitted.

Sample area	Northern Sector								Central Sector								Southern Sector							
Depth range (m)	0 - 10		10 - 20		20 - 30		30+		0 - 10		10 - 20		20 - 30		30+		0 - 10		10 - 20		20 - 30		30+	
Length group (T.L. in cm)	No of fish	Sex ratio	No of fish	Sex ratio	No of fish	Sex ratio	No of fish	Sex ratio	No of fish	Sex ratio	No of fish	Sex ratio	No of fish	Sex ratio	No of fish	Sex ratio	No of fish	Sex ratio	No of fish	Sex ratio	No of fish	Sex ratio	No of fish	Sex ratio
12-14	-	-	-	-	-	-	-	-	-	-	11	120*	-	-	15	114*	-	-	-	-	-	-	-	-
14-16	-	-	-	-	14	180*	-	-	-	-			45	73*			-	-	-	-	-	-	29	123*
16-18	-	-	19	375			-	-	34	79*	60	114*					-	-	-	-	98	100*		
18-20	16	220*					3	-			227	187	211	122*	51	132*	-	-	-	-				
20-22			23	156*	11	120*	-	-	87	190	345	174	460	142	46	360	-	-	-	-				
22-24	11	120*	26	160*	23	92*	-	-	103	296	281	173	497	124	36	200	-	-	-	-			104	100*
24-26	18	200*	19	90*	57	159*	-	-	73	329	256	169	397	132	44	214	1	-	-	-				
26-28	12	200*	38	217	89	117*	1	-	63	215	271	108*	551	49	79	182	1	-	1	-				
28-30	14	75*	45	275	124	188	-	-	70	94*	350	99*	401	76	75	241	2	-	-	-				
30-32	10	150*	52	189	90	291	-	-	81	131*	417	117*	446	68	75	241	3	-	-	-	54	80*	24	500
32-34	10	400*	33	200*	63	200	-	-	88	184	334	155	475	64	75	295	4	-	3	-				
34-36	12	200*	22	267	64	256	-	-	61	205	235	106*	191	88*	60	500	6	-	1	-				
36-38			20	900	29	383	-	-	43	378	121	152	167	74*	47	262	4	-	-	-				
38-40			16	350	28	250	-	-	29	190*	62	158*	83	102*	25	733	1	-	-	-				
40-42			37	208	34	467	-	-	38	443	87	314	77	413	60	1100	-	-	-	-				
42-44							-	-									-	-	-	-	-	-		
44-46							-	-									-	-	-	-	-	-		
46-48							-	-									-	-	-	-	-	-		
48-50					25	317	-	-									-	-	-	-	-	-		
50-52							-	-									-	-	-	-	-	-		
52-54							-	-									-	-	-	-	-	-	-	-
54-56	-	-					-	-									-	-	1	-	-	-	-	-
56-58	-	-					-	-									-	-	-	-	-	-	-	-
58-60	-	-	-	-			-	-	-	-							-	-	-	-	-	-	-	-
Total	103	151	362	229	663	207	4	-	770	196	3067	140	4012	91	723	379	22	38	6	20*	150	92*	157	128*
Number of stations	8		13		12		1		26		46		55		53		3		2		6		11	

TABLE 11.29

Showing annual variation in the sex ratio of all *Lates longispinis* caught by bottom trawl in four depth zones and in three seasons in the Ferguson's Gulf area during the period June 1972 to August 1975. The sex ratio is expressed as numbers of females per 100 males in each length group. Ratios which are not significantly different from 100 (chi-squared < 3.841) are marked with an asterisk. Sex ratios for samples of less than 5 fish of one sex are not recorded.

Sample months	November - February								March - June								July - October							
Depth range (m)	0-10		10-20		20-30		30+		0-10		10-20		20-30		30+		0-10		10-20		20-30		30+	
Length group (T.L. in cm)	No of fish	Sex ratio	No of fish	Sex ratio	No of fish	Sex ratio	No of fish	Sex ratio	No of fish	Sex ratio	No of fish	Sex ratio	No of fish	Sex ratio	No of fish	Sex ratio	No of fish	Sex ratio	No of fish	Sex ratio	No of fish	Sex ratio	No of fish	Sex ratio
< 20	31	72*	101	159	165	123*	-	-	1	-	51	82*	49	58*	12	200*	1	-	143	218	17	240*	23	91*
20-22	84	180	157	134*	233	153	-	-	1	-	80	129*	124	103*	13	1200	2	-	104	333	26	160*	17	240*
22-24	92	318	140	155	202	169	3	-	1	-	64	256	180	125*	6	100*	8	167*	75	159	26	160*	14	600
24-26	70	367	113	277	102	176	-	-	1	-	84	171	157	145	18	200*	2	-	53	77*	30	100*	8	300*
26-28	49	250	94	114*	102	155	3	-	7	40*	99	161	123	112*	26	160*	6	500*	74	64*	37	61*	18	350
28-30	53	141*	86	91*	126	94*	-	-	13	18	139	223	107	73*	28	211*	4	-	128	49	55	112*	19	850
30-32	59	146*	136	81*	140	100*	-	-	15	200*	118	307	113	55	21	320	6	0	153	91*	59	103*	19	533
32-34	54	184	103	129*	96	118*	1	-	18	157*	103	390	95	48	23	360	11	267*	120	103*	68	94*	21	425
34-36	32	300	81	119*	91	122*	3	-	14	180*	54	200	76	95*	20	300	4	-	87	74*	40	111*	20	∞
36-38	22	633	39	200	54	108*	3	-	8	167*	30	200*	38	90*	11	267*	5	-	40	122*	25	178*	15	1400
38-40	13	225*	18	200*	24	243	1	-	6	500*	15	114*	18	100*	6	∞ *	3	-	23	188*	14	133*	12	∞
> 40	16	433	31	1450	21	600	5	∞	9	800	9	200*	9	350*	14	1300	4	-	37	363	15	400	24	2300
Total	575	216	1099	140	1356	136	19	850	94	141*	846	201	1089	93*	198	281	57	171	1037	115	413	117*	210	483
Number of stations	4		14		13		8		5		6		9		12		3		17		14		18	

TABLE 11.30

Food of all *Lates longispinis* caught by bottom trawling in all depth zones throughout Lake Turkana from June 1972 to November 1974. Points for each food item are expressed as percentages of the total points in each size group.

Length group (T.L. in cm)	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60
Number of stomachs	1	36	101	207	227	328	419	188	48	14	11	1
% empty	0	8	19	29	16	18	25	37	31	29	45	0
Food items												
Crustacea :-												
Macrobrachium niloticum	-	-	3	14	5	11	14	8	6	-	-	-
Caridina nilotica	-	47	18	-	-	-	+	-	-	-	-	-
Unidentified prawns	100	49	71	76	87	72	58	35	17	8	-	-
Total prawns	100	97	91	89	92	83	72	43	22	8	-	-
Fish :-												
Hydrocynus forskalii	-	-	-	-	-	+	-	2	-	-	-	-
Alestes ferox	-	-	-	2	+	5	9	12	19	7	33	100
Alestes minutus	-	-	-	-	-	+	+	1	-	-	-	-
Engraulicypris stellae	-	-	1	1	1	+	3	2	11	-	-	-
Barbus turkanae	-	-	-	-	-	-	+	-	-	-	-	-
Barbus spp.	-	-	-	1	1	+	-	-	-	5	-	-
Bagrus bayad	-	-	-	2	-	-	-	2	-	-	-	-
Chrysichthys auratus	-	-	-	-	-	-	1	1	-	-	-	-
Lates spp.	-	-	-	-	-	1	1	-	-	-	-	-
Haplochromis macconneli	-	-	-	1	-	-	+	1	-	-	-	-
Tilapia spp.	-	-	-	-	1	-	-	-	-	-	-	-
Unidentified fish	-	-	5	4	6	10	13	35	48	18	67	-
Total fish	-	-	6	10	8	17	28	56	78	93	100	100
Insects :-												
Corxids	-	3	3	1	+	-	-	+	-	-	-	-
Anisopteran nymphs	-	-	-	-	-	-	-	1	-	-	-	-
Unidentified insects	-	-	-	-	-	-	-	-	-	-	-	-
Total insects	-	3	3	1	+	-	-	1	-	-	-	-
Total food	25	41	30	20	31	33	28	20	19	18	17	13

TABLE 11.31

Food of *Lates longispinis* of 20-40cm T.L. caught during the current survey by bottom trawling in the Ferguson's Gulf area, for two periods of the year, May-August and September-April, in five different depth zones. Points for each food item are expressed as a percentage of the total food items ingested by fish sampled from within one depth zone.

	May to August					September to April	
Depth zone (m)	0-10	10-20	20-30	30-40	40+	30-40	40+
Number of stomachs	25	200	53	9	1	8	7
% empty	32	20	32	33	0	75	57
Food items							
Crustacea :-							
Macrobrachium niloticum	-	1	16	10	-	-	-
Unidentified prawns	49	83	37	76	100	63	67
Total prawns	49	84	53	86	100	63	67
Fish :-							
Alestes ferox	13	8	6	-	-	-	-
Alestes minutus	-	-	1	-	-	-	-
Engraulicypris stellae	-	+	8	10	-	-	-
Barbus spp.	-	-	-	-	-	38	-
Chrysichthys auratus	2	-	-	-	-	-	-
Unidentified fish	35	7	31	5	-	-	33
Total fish	51	16	47	14	-	38	33
Insects :-							
Corxids	-	+	-	-	-	-	-
Total insects	-	+	-	-	-	-	-
Total food	22	34	22	15	13	6	11

Seasonal changes in the food of Lates longispinis in three length classes. Fish were caught by bottom trawling at all depths throughout Lake Turkana during the period June 1972 to November 1974. Points for each food item are expressed as a percentage of the monthly total of food ingested.

Year	1972							1973												1974										
Month	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
10-20cm T.L.																														
No of stomachs	-	16	20	59	41	2	1	2	19	1	6	23	13	15	26	40	-	4	-	-	7	-	-	1	4	-	-	1	-	5
% empty	-	0	5	29	41	-	-	-	-	-	17	61	8	47	19	28	-	25	-	-	29	-	-	0	0	-	-	0	-	40
Food :																														
Prawns	-	100	100	95	100	100	100	100	96	-	86	61	96	90	73	86	-	100	-	-	78	-	-	100	92	-	-	100	-	100
Fish	-	-	-	5	-	-	-	-	4	100	14	39	4	10	18	6	-	-	-	-	22	-	-	-	8	-	-	-	-	-
Insects	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-
All food	-	43	29	17	8	22	63	56	55	63	44	19	25	16	24	21	-	23	-	-	16	-	-	25	41	-	-	38	-	15
20-30cm T.L.																														
No of stomachs	3	51	23	15	20	7	5	9	80	24	56	25	7	10	25	46	3	7	2	9	17	12	11	23	23	4	-	5	1	3
% empty	100	2	22	53	60	-	20	11	5	8	5	28	71	40	16	37	20	57	-	-	18	42	-	-	13	-	-	-	-	67
Food :																														
Prawns	-	90	93	91	100	70	95	100	97	90	84	82	74	71	48	86	59	100	100	64	87	44	100	85	71	100	-	85	33	100
Fish	-	10	7	9	-	30	5	-	3	10	16	18	26	29	50	14	41	-	-	36	13	56	-	15	29	-	-	15	67	-
Insects	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
All food	0	44	31	10	5	21	25	63	45	23	42	30	41	19	13	23	17	11	31	40	22	17	56	54	24	31	-	33	38	25
30-40cm T.L.																														
No of stomachs	8	51	59	13	12	5	14	20	39	17	84	50	21	19	22	41	34	6	7	8	3	13	2	23	21	8	-	2	3	5
% empty	38	14	39	46	25	-	7	55	31	29	2	38	33	37	41	37	44	50	43	-	-	46	50	13	14	25	-	-	100	60
Food :																														
Prawns	-	78	53	100	86	93	69	99	87	61	59	39	48	55	14	77	52	80	90	80	100	38	100	73	42	90	-	75	-	17
Fish	75	22	46	-	14	7	31	1	13	39	41	61	52	45	86	23	48	20	10	20	-	62	-	27	58	10	-	25	-	83
Insects	25	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
All food	13	40	19	13	11	19	24	25	33	28	39	16	14	18	16	17	12	10	18	55	50	13	31	40	37	31	-	25	-	15

Food of *Lates longispinis* caught (a) by bottom trawling between the months of September and November 1972-1974, and (b) by trawling in midwater between the months of September 1975 and November 1975. Points for each food item are expressed as percentages of the total possible points in each size class, with the percentage of the total points scored by food items in brackets.

	(a) Demersal *L. longispinis* caught in the bottom trawl					(b) Pelagic *L. Longispinis* caught in the Boris midwater trawl				
Length group (T.L. in cm)	0-10	10-20	20-30	30-40	40+	0-10	10-20	20-30	30-40	40+
Number of stomachs	3	153	134	121	16	6	112	62	92	11
% empty	67	32	37	40	56	83	47	40	30	27
Food items :										
Crustacea :-										
Macrobrachium niloticum	-	2 (15)	2 (12)	2 (11)	+ (6)	-	1 (5)	-	-	-
Caridina nilotica	-	+ (2)	-	+ (1)	-	-	-	-	-	-
Unidentified prawns	8 (100)	12 (76)	12 (68)	8 (60)	4 (56)	1 (100)	5 (30)	5 (23)	2 (10)	5 (13)
Total prawns	8 (100)	15 (93)	14 (80)	10 (72)	4 (61)	1 (100)	6 (35)	5 (23)	2 (10)	5 (13)
Fish :-										
Hydrocynus forskalii	-	-	+ (+)	-	-	-	-	-	-	-
Alestes ferox	-	-	1 (5)	1 (5)	-	-	1 (4)	3 (14)	4 (15)	5 (13)
Alestes minutus	-	-	-	-	-	-	5 (32)	10 (47)	16 (68)	22 (61)
Engraulicypris stellae	-	-	-	-	-	-	-	+ (1)	-	-
Barbus spp.	-	+ (1)	+ (2)	-	-	-	-	-	-	-
Bagrus bayad	-	-	-	+ (1)	-	-	-	-	-	-
Chrysichthys auratus	-	-	-	1 (6)	-	-	-	-	-	-
Lates spp.	-	-	-	-	-	-	-	-	+ (1)	-
Haplochromis macconneli	-	+ (2)	-	-	-	-	-	-	-	-
Tilapia spp.	-	-	+ (2)	-	-	-	-	-	-	-
Unidentified fish	-	+ (2)	2 (11)	2 (16)	3 (39)	-	5 (28)	3 (15)	2 (6)	5 (13)
Total fish	-	1 (4)	3 (20)	4 (28)	3 (39)	-	11 (64)	17 (27)	22 (90)	31 (87)
Insects :-										
Corixids	-	+ (3)	-	-	-	-	+ (1)	-	-	-
All insects	-	+ (3)	-	-	-	-	+ (1)	-	-	-
All food	8	16	17	14	7	1	17	22	24	35

TABLE 11.34

Regional study of the food of pelagic *Lates longispinis* of 8 to 50cm T.L. during a lakewide series of cruises with the Boris midwater trawl, between September and November 1975. The number of points awarded to each food item has been expressed as a percentage of the total possible score, and the same number expressed as a percentage of the total actual score is shown in brackets.

Sector	Northern Sector	Northern half of Central Sector	Southern half of Central Sector	Southern Sector
Size range (T.L. in cm)	9-46	8-50	10-43	8-36
Number of stomachs	49	138	89	7
% empty	61	41	31	0
Food items				
Crustacea :-				
Macrobrachium niloticum	-	1 (4)	-	-
Unidentified prawns	2 (17)	5 (27)	4 (14)	5 (26)
Total prawns	2 (17)	5 (31)	4 (14)	5 (26)
Fish :-				
Alestes minutus	3 (30)	7 (39)	19 (75)	4 (17)
Alestes ferox	2 (14)	2 (11)	+ (1)	7 (34)
Engraulicypris stellae	-	+ (1)	+ (1)	-
Lates spp.	-	-	+ (1)	-
Unidentified fish	4 (40)	3 (19)	2 (8)	4 (21)
Total fish	9 (83)	12 (69)	22 (85)	15 (75)
Total insects	-	-	-	-
Total food	11	18	26	21

TABLE 11.35

Diel study of the food of *Lates longispinis* of 2-31cm T.L. caught during a 24 hour cycle at a station in 24 metres of water off Longech Spit in the framed trawl during April 1974. Points for each food item are expressed as a percentage of the total possible points for each sampling period, with the percentage of the total points scored by food items in brackets.

Time (E.A.T.) hrs.	13.15-15.05	17.10-18.56	22.50-01.58	06.28-08.18	11.00-12.45
Length range (T.L. in cm)	3-22	2-23	2-31	2-24	2-17
Number of stomachs	11	11	32	13	20
% empty	9	27	47	0	25
Food items :					
Crustacea :-					
Macrobrachium niloticum	-	4 (8)	1 (6)	5(13)	9(37)
Cardinia nilotica	63(98)	39(76)	14(63)	27(67)	12(49)
Unidentified prawns	-	7(15)	2 (7)	1 (4)	3(13)
Total prawns	63(98)	50(99)	17(76)	34(83)	23(99)
Fish :-					
Engraulicyptis stellae	1 (2)	-	4(16)	7(17)	-
Unidentified fish	-	-	2 (7)	-	-
Total fish	1 (2)	-	5(23)	7(17)	-
Insects :-					
Corixids	-	1 (1)	+ (1)	-	+ (1)
Total food	64	51	23	40	24

TABLE 11.36

Diel study of the food of *Lates longispinis* of 7 to 31 cm T.L. during a 24 hour cycle at a station 3 km east of Longech Spit at a lake depth of 27 metres, on 24-25 October 1975. The number of points awarded to each food item has been expressed as a percentage of the total possible score and the same number, expressed as a percentage of the total actual score is shown in brackets.

Time (hrs) E.A.T.)	11.09	15.05	19.05	23.12	03.05	07.15	10.39
Size range (T.L. in cm)	7-28	10-21	10-21	11-28	10-31	9-29	10-33
Number of stomachs	73	70	45	15	23	26	22
% empty	27	29	36	0	8	15	55
Food items :							
Crustacea :-							
Total prawns	10(52)	6(28)	7(50)	12(43)	8(26)	16(54)	10(70)
Fish :-							
Alestes minutus	2(10)	9(45)	3(20)	7(25)	10(32)	9(30)	1(10)
Alestes ferox	-	-	-	-	3 (9)	-	-
Engraulicypris stellae	+ (1)	-	-	-	-	-	-
Unidentified fish	7(37)	5(27)	4(30)	9(32)	10(33)	5(15)	3(20)
Total fish	9(48)	14(72)	7(50)	16(57)	33(74)	14(45)	4(30)
Total insects	+ (+)	-	-	-	-	-	-
Total food	19	20	14	27	32	30	14

TABLE 11.37

Showing the incidence of the copeped ectoparasite Opistholernaea longa on Lates longispinis caught by bottom trawling during the present investigations, in five depth zones in three sectors of Lake Turkana, and the mean rate of incidence for the lake as a whole. The rate of incidence was calculated as the number of parasitised fish expressed as a percentage of the total number of fish caught in all standard hauls taken in each depth zone.

Depth zone (m)	0-10	10-20	20-30	30-40	40+
Northern Sector					
Number of stations	6	16	14	2	1
Number of fish	272	2314	3711	28	36
% with O. longa	-	7.3	3.9	71.4	-
Central Sector					
Number of stations	23	49	62	24	45
Number of fish	2733	23091	34869	5211	2286
% with O. longa	-	+	2.2	12.1	6.8
Southern Sector					
Number of stations	1	3	3	7	13
Number of fish	3	112	24	1501	735
% with O. longa	-	-	-	-	14.7
Entire Lake					
Number of stations	30	68	79	33	59
Number of fish	3008	25517	38604	6860	3057
Size range (T.L. in cm)	-	12-47	6-58	13-50	23-46
% with O. longa	-	0.7	2.4	9.7	8.6
Mean number of O. longa per parasitised fish (± SD)	-	8.6(±7.5)	7.2(±8.7)	5.3(±8.7)	13.9(±14.7)

TABLE 11.38

Showing the seasonal variation in the incidence of the copepod ectoparasite Opistholernaea longa on Lates longispinis caught by bottom trawling during the present investigations in three sectors of the lake, during three seasons of the year. The rate of incidence was calculated as the number of parasitised fish expressed as a percentage of the total number of fish caught per season. The number of Lates longispinis caught per season was calculated as the sum of the number caught per standard haul.

SEASON	(Mar-Jun)	(Jul-Oct)	(Nov-Feb)
Northern Sector			
Number of stations	13	17	9
Number of fish	2128	1642	2691
Size range (T.L. in cm)	-	10-47	12-47
% with O. longa	-	9.1	7.1
Mean number of O. longa per parasitised fish (± SD)	-	5.8 (±4.6)	8.8 (±5.7)
Central Sector			
Number of stations	54	91	58
Number of fish	19068	26611	21531
Size range (T.L. in cm)	31-46	6-58	11.57
% with O. longa	0.1	3.8	2.4
Mean number of O. longa per parasitised fish (± SD)	11.5 (±4.9)	5.9 (±10.3)	9.3 (±8.8)
Southern Sector			
Number of stations	18	2	7
Number of fish	1711	204	356
Size range (T.L. in cm)	26-33	-	-
% with O. longa	6.0	-	-
Mean number of O. longa per parasitised fish (± SD)	9.5 (±4.5)	- -	- -

TABLE 11.39

Changes in commercial gillnet fishery catches in Lake Turkana for the three main species involved. Annual weights in tonnes. Monthly catches of Sarotherodon niloticus from Ferguson's Gulf for the years 1975 and 1976 appear below.

	Citharinus citharus	Labeo horie	Sarotherodon niloticus
1972	666	586	131
1973	400	794	217
1974	108	1034	447
1975	10	466	1996
1976			16120*

*Estimate for 1976 based on first 8 months catches.

Sarotherodon niloticus: catches from Ferguson's Gulf (based on tax receipts) in tonnes. The 1976 total is based on data for the first 8 months.

Month	1975	1976
Jan	119	290
Feb	196	661
Mar	230	1034
Apr	287	1202
May	236	1393
Jun	216	1849
Jul	139	2000
Aug	116	2317
Sep	96	
Oct	85	
Nov	128	
Dec	148	
Total	1996	16120

TABLE 11.40

Mean catch per effort for the large cychlid species in Lake Turkana, from 341 quantitative bottom trawl hauls analysed on the basis of depth, in kg/hr. A + sign indicates a catch per effort of less than 0.1 kg/hr.

Depth Zone (m)	*S. niloticus*	*S. galilaeus*	*T. zillii*	Station frequency
0-5	59.6	+	+	16
5-10	5.8	+	+	38
10-15	0.3	-	+	36
15-20	+	-	+	45
20-25	0.1	-	-	47
25-30	+	-	-	35
over 30	-	-	-	124

TABLE 11.41

Showing the relative proportions of *Sarotherodon niloticus*, *Sarotherodon galilaeus* and Tilapia zillii caught in beach seine hauls in Ferguson's Gulf during the present study. The frequency of each species has been expressed as a percentage of their combined totals. Date for two types of net are presented separately.

Net length (m)	Mesh size (mm)	*S. niloticus* %	*S. galilaeus* %	*T. zillii* %	Total n
50	19	86	14	+	2858
100	102	87	13	-	924

TABLE 11.42

Showing the relative proportion of Sarotherodon niloticus, Sarotherodon galilaeus and Tilapia zillii caught in beach seine hauls in various regions of the shore throughout the main lake during the present study. The frequency of each species has been expressed as a percentage of their combined totals.

Region	S. niloticus %	S. gallilaeus %	T. zillii %	Total number
Ilaret	99	1	-	457
Koobi Fora	91	9	+	2249
Allia Bay	65	3	32	2066
Jarigole	100	-	-	3
Moite	97	3	+	1527
Sandy Bay	94	4	2	1357
El Molo Bay	68	7	24	776
Sirima Head	58	35	7	45
South Island	98	-	2	56
Mugurr	100	-	-	11
Kerio-Meriar	60	40	-	644
Lolibekai	82	18	-	92
Todenyang	100	-	-	13

TABLE 11.43

Mean number of fry of each species (under 5.0cm T.L.) caught per haul with fine foot seine nets in Ferguson's Gulf. Site numbers are shown in Figure 11.6.

Site	*S. niloticus*	*S. galilaeus*	*T. zillii*	Number of hauls
1	6.2	-	-	9
2	18.4	-	1.0	5
3	51.8	0.9	0.5	31
4	99.0	-	-	2
5	2.0	-	3.0	5
6	2.3	-	-	22
7	14.3	-	0.1	10
8	18.0	-	-	1

TABLE 11.44

Selectivity of gillnets in respect of Sarotherodon niloticus in Lake Turkana, showing mean retention lengths for six mesh sizes in catches during the present study.

Stretched mesh size (inches)	Total length (cm)	
	mean	standard deviation
3	19.44	± 0.31
3½	22.99	± 0.25
4	24.58	± 0.21
4½	27.92	± 0.18
5	29.77	± 0.10
6	33.91	± 1.37

TABLE 11.45

The relationship between length (l in cm) and wet weight (w in g) for *Sarotherodon niloticus*, where $w = a\,l^b$. Values of a and b are given for various localities, length groups and different sexes. Values of r^2 from the regression $\log w = \log a + b \log l$ are also given.

Locality/date		Group	Sample size(n)	a	b	r^2
Ferguson's Gulf						
Gillnets	21/2/1975	Immature males	22	-1.36	2.74	0.966
		Immature females	36	-1.42	2.79	0.957
		Mature males	37	-1.80	3.08	0.995
		Mature females	35	-1.69	3.00	0.986
Beach seine	April 1974	All fish	89	-1.55	2.94	0.994
	May 1974	All fish	75	-1.55	2.91	0.988
	7/5/1974	Mature males	32	-1.67	3.00	0.987
	7/5/1974	Mature females	37	-1.75	3.06	0.994
	27/6/1974	All fish	6	-1.94	3.17	0.999
	17/4/1975	All fish	36	-1.78	3.04	0.986
Moite						
Beach seine	26/1/1973	Immature males	35	-1.11	2.61	0.963
		Immature females	38	-1.35	2.80	0.977
		Mature males	27	-1.27	2.77	0.990
		Mature females	19	-1.12	2.67	0.979
Allia Bay						
Beach seine	25/1/1973	All males	24	-1.70	3.02	0.997
		All females	21	-1.46	2.87	0.992
	21/2/1973	All males	25	-1.68	3.01	0.996
		All females	25	-2.10	3.34	0.984
Sandy Bay						
Beach seine	10/8/1974	All fish	8	-1.62	2.96	0.997
All fish in study from all localities			628	-1.63	2.99	0.89

TABLE 11.46

Showing numbers of immature and mature individuals recorded in each 1cm length class for male and female *Tilapia zillii.*

Total length (cm)	Males immature	Males mature	Females immature	Females mature
7	-	-	-	-
8	2	1	-	1
9	-	-	1	1
10	1	-	5	-
11	4	1	2	2
12	4	2	3	2
13	1	1	4	-
14	2	-	1	-
15	2	1	3	-
16	-	1	2	-
17	4	-	1	-
18	-	-	1	2
19	2	-	2	-
20	4	-	3	-
21	2	-	1	2
22	4	2	4	-
23	3	1	2	2
24	2	8	1	-
25	1	1	-	-
26	3	2	-	-
27	1	-	-	1
28	-	-	-	-
29	-	1	-	-
30	-	-	-	-
31	-	-	-	-
32	-	1	-	-
33	-	1	-	-

TABLE 11.47

Showing information on maturity sizes of the three large cichlid species in Lake Turkana. The columns headed '50%' represent the length at which 50% of the populations are mature. Percentage maximum length and percentage maximum weight indicate percentage of maximum length and weight achieved by the fish, e.g. the smallest mature male Sarotherodon niloticus measured 45.4% of the total length of the largest male S. niloticus and 13% of the weight of the largest male S. niloticus.

	Length at maturity (cm)			% Maximum length		Weight at maturity (g)			% Maximum weight	
Species	Min.	50%	Max.	Min.	50%	Min.	50%	Max.	Min.	50%
S. niloticus										
Male	24.5	32.2	54.0	45.4	60.1	330	756	3480	13.0	21.7
Female	24.5	29.6	49.0	50.0	59.6	330	588	2550	13.0	23.0
S. galilaeus										
Male	22.0	23.2	36.0	61.1	64.4	257	302	1134	22.7	26.6
Female	20.0	22.7	34.0	58.8	66.8	195	282	912	21.4	30.9
T. zillii										
Male	8.0		33.0	24.2		10.0		590	1.7	
Female	8.0		27.0	29.6		10.0		340	2.9	

TABLE 11.48

Seasonal changes in the numbers of female *Sarotherodon niloticus* observed in breeding condition in Ferguson's Gulf during 1975-1976.

Month	Total number of females	Number of females in breeding condition
January	4	1
February	69	2
March	10	5
April	40	10
May	121	35
June	21	8
July	124	33
August	4	3
September	1	1
October	4	3
November	3	2
December	4	2

TABLE 11.49

Showing sex-ratios recorded for *Sarotherodon niloticus* from hauls throught the present study.

Size class (T.L. in cm)	Number of males	Number of females	Number of males per female
16.0-20.9	151	154	0.98
21.0-25.9	518	550	0.94
26.0-30.9	439	495	0.89
31.0-35.9	155	172	0.90
36.0-40.9	134	107	1.25
41.0-45.9	59	52	1.13
46.0-50.9	60	14	4.29
51.0-55.9	27	0	∞
Overall ratio :	1543	1544	1.0

TABLE 11.50

Showing sex-ratios recorded for *Sarotherodon galilaeus* from hauls throughout the present study.

Size class (T.L. in cm)	Number of males	Number of females	Number of males per female
11.0-15.9	16	19	0.84
16.0-20.9	49	57	0.86
21.0-25.9	91	114	0.80
26.0-30.9	27	23	1.13
31.0-35.9	18	16	1.13
Overall ratio :	202	229	0.88

TABLE 11.51

Showing values of coefficients a and b for linear regressions of dry weight of stomach contents against wet weight of fish (all in g) for samples of *Sarotherodon niloticus* collected at various times throughout the diel cycle. Data from all localities have been combined. The value of r^2, the coefficient of determination for each regression is also given.

Time (hrs E.A.T.)	Sample size (n)	Size range (cm T.L.)	Coefficients a	b	r^2
04.00	5	24.0-31.0	+1.63	-0.0017	-0.47
06.00	10	26.0-29.0	+0.05	0.0004	0.24
07.30	5	19.0-24.2	-0.044	0.00006	0.22
09.45	8	19.0-25.0	+0.06	-0.00003	-0.64
10.50	9	16.0-19.0	-0.29	0.0029	0.50
11.00	9	18.0-28.0	-0.13	0.00045	0.89
11.15	14	19.0-29.0	+0.03	0.0009	0.64
11.30	8	17.0-25.5	+0.02	0.00069	0.97
12.00	6	17.0-28.0	-0.05	0.0007	0.99
13.35	6	17.0-23.5	-0.07	0.0015	0.35
17.00	3	18.0-28.0	-0.78	0.0034	0.67
17.30	18	21.0-29.5	-0.47	0.00082	0.96
18.00 (i)	22	22.0-29.0	+0.80	0.0014	0.94
18.00 (ii)	9	24.0-29.8	+0.25	0.001	0.92
18.30	13	21.0-29.5	+1.03	-0.0008	-0.36

TABLE 11.52

Total daily ingested dry weight of food by *S. niloticus*. All weights are in grammes.

Fish wet weight	Stomach 100%	w_3	Intestine 100%	w_4	Total $w_3 + w_4$
200	0.40	0.42	0.67	1.84	2.26
500	0.78	0.81	1.90	5.23	6.04
1000	1.30	1.35	4.24	11.66	13.01

TABLE 11.53

Comparison of estimates of daily intake of food (dry weight in grammes) by *S. niloticus* of three different sizes (wet weight in grammes) obtained during recent studies.

Wet weight fish (g)	200	500	1000
MORIARTY (1973)	2.73	6.72	13.57
HARBOTT (1975)	2.22	5.75	11.10
Present study	2.26	6.04	13.01

TABLE 11.54

Showing food items recorded from stomachs of *Sarotherodon niloticus* between 1.1-5.0cm T.L. on the east shore of Ferguson's Gulf on 16-17/4/1975. Occurrence is indicated as percentage of stomachs containing the food items, at each station.

	Time E.A.T.					
Algal material	03.15	06.30	10.30	12.30	17.15	21.30
Anabaena circinalis	-	42	90	94	97	11
Anabaena constricta	3	5	-	11	-	-
Anabaena variabilis	-	53	10	22	16	-
Anabaena sp.	13	5	10	33	-	-
Chroococcus minutus	-	42	90	72	90	-
Lyngbya lucidum	-	58	20	78	23	-
Microchaete tenera	-	26	10	-	16	-
Oscillatoria curviceps	-	-	-	-	87	-
Oscillatoria schultzii	13	79	100	100	97	5
Phormidium tenue	22	42	40	94	90	11
Phormidium molle	3	-	-	-	-	-
Spirulina laxissima	7	94	100	100	100	11
Spirulina platensis	-	37	100	72	90	16
Spirulina subsala	-	5	-	-	-	-
Synechocystis aquatilis	-	-	-	6	-	-
Anomoneis sphaerophora	23	84	100	94	100	11
Coscinodiscus rudolfii	-	-	50	11	19	-
Cymbella lanceolata	-	-	-	11	-	11
Cymbella mulleri	3	-	-	-	-	-
Cyclotella meneghiniana	7	58	40	83	90	5
Fragilaria construens	3	44	90	50	77	-
Gomphocymbella beccari	7	26	-	-	3	11
Navicula placentula	7	42	60	22	90	5
Navicula pupula	-	58	90	76	81	5
Navicula tuscula	13	58	100	94	77	5
Nitzchia spp.	23	95	100	100	100	11
Rhopalodia gibba	-	5	-	6	3	-
Rhopalodia gibberula	3	74	100	94	97	11
Rhopalodia gracilis	-	42	60	44	87	5
Rhopalodia hirudinalis	13	5	30	17	23	5
Rhopalodia ventricosa	-	26	10	11	6	5
Rhopalodia vermicularis	-	26	10	56	32	-

contd/

TABLE 11.54 (contd.)

	Time E.A.T.					
Algal material	03.15	06.30	10.30	12.30	17.15	21.30
Stephanodiscus astraea	-	-	-	11	-	-
Surirella biseriata	-	-	10	-	10	-
Gymnodinium aeruginosum	3	32	50	94	97	16
Oedogonium sp.	-	16	-	-	-	-
Planctonema lauterbornii	-	-	-	-	3	-
Tetrastrum heteracanthum	-	5	40	44	84	-
Scenedesmus quadricauda	-	-	-	17	13	5
Animal material						
Epistylis	10	5	30	-	-	-
Ostracod remnants	3	-	-	-	-	5
Corixid spp. - adults	16	16	-	-	-	-
Chironomid spp. - larvae	45	47	-	-	-	16
Number of fish	31	19	11	18	31	18

TABLE 11.55

Showing the occurrence of individuals of nine algal species in the plankton (i) and stomachs of *Sarotherodon niloticus* (ii) as percentages of total algal counts. Fish ranged from 3.0 - 3.25cm T.L. and were caught at 12.30 hrs E.A.T. in Ferguson's Gulf.

	(i) Plankton	(ii) Stomachs
Anabaena circinalis	7.3	9.3
Chroococcus minutus	2.2	0.5
Oscillatoria schultzii	1.2	0.2
Spirulina laxissima	50.0	59.6
Spirulina platensis	0.4	0.1
Synechocystis aquatilis	30.4	0.0
Anomoneis sphaerophora	0.1	1.32
Nitzschia spp.	3.7	28.5
Gymnodinium aeruginosum	0.1	0.1

TABLE 11.56

Major algal species occurrence in the stomachs of *Sarotherodon niloticus* fry on the east shore of Ferguson's Gulf, April 1975, 12.30 hrs E.A.T. Proportions of the total stomach contents are shown as percentage volumes. (Fish from 3.0-3.25cm T.L.)

Algae	Units	Number/ stomach	Volume/ stomach (μm^3)	Percentage volume	Group total
Anabaena circinalis	Coils	49,262	154,800,000	72.06	75.11 % volume
Chroococcus minutus	Cells	2,612	22,202	0.01	
Oscillatoria schultzii	Filaments	947	700,780	0.33	
Spirulina laxissima	Coils	314,187	4,712,805	2.19	
Spirulina platensis	Coils	373	1,124,968	0.52	
Anomoneis sphaerophora	Cells	6,953	16,687,200	7.77	22.85 % volume
Cyclotella meneghiniana	Cells	877	1,552,290	0.72	
Fragilaria construens	Cells	140	3,500	0.0016	
Navicula pupula	Cells	420	336,000	0.16	
Nitzschia spp.	Cells	150,213	30,042,600	13.98	
Rhopalodia gibba	Cells	93	186,000	0.09	
Rhopalodia gibberula	Cells	560	268,800	0.13	
Gymnodinium aeruginosum	Cells	746	4,103,000	1.91	1.91 % volume
Planctonema lauterbornii	Cells	93	288,300	0.13	0.13 % volume

TABLE 11.57

Showing food items recorded from stomachs of Sarotherodon niloticus (n=35) caught in Ferguson's Gulf on 16/4/75. Occurrence is given as percentage of stomachs containing the item. Total length of fish ranged from 24.2-35.6cm.

Food item	% occurrence
Anabaena circinalis	85.7
Anabaena constricta	5.7
Anabaena variabilis	5.7
Anabaena sp.	28.6
Chroococcus minutus	62.9
Dactylococcopsis raphidiodes	11.4
Lyngbya lucidum	22.9
Microchaete tenera	2.9
Oscillatoria schultzii	91.5
Phormidium tenue	77.1
Spirulina laxissima	97.1
Spirulina platensis	71.4
Synechocystis aquatilis	91.4
Anomoneis sphaerophora	8.6
Coscinodiscus rudolfii	5.7
Cyclotella meneghiniana	40.0
Fragilaria construens	2.9
Navicula placentula	5.7
Navicula pupula	2.9
Nitzschia spp.	97.1
Rhopalodia gracilis	2.9
Surirella biseriata	2.9
Scenedesmus quadricauda	11.4
Tetrastrum heteracanthum	71.4
Rotifer remnants	31.4
Ostracod remnants	14.3
Corixis remnants	2.9
Chironomid remnants	2.9
Zooplankton remnants	14.3

TABLE 11.58

Occurrence of nine algal species in the plankton (i) and stomachs of Sarotherodon niloticus (ii) as percentages of total algal counts. Fish ranged from 24.2-35.6cm T.L. and were caught at 10.30 hrs E.A.T. in Ferguson's Gulf.

Alga	Plankton (i)	Stomachs (ii)
Anabaena circinalis	5.3	8.5
Chroococcus minutus	1.0	1.0
Oscillatoria schultzii	1.0	1.0
Spirulina laxissima	41.0	39.0
Spirulina platensis	1.0	3.3
Synechocystis aquatilis	36.7	34.0
Anomoneis sphaerophora	0.1	0.1
Nitzschia spp.	9.3	6.8
Gymnodinium aeruginosum	0.1	0.0

TABLE 11.59

Occurrence of nine algal species in the planktonic (i) and stomachs of Sarotherodon niloticus (ii) as percentages of total algal volumes. Fish ranged from 24.2-35.6cm and were caught at 10.30 hrs E.A.T. in Ferguson's Gulf.

Alga	Plankton (i)	Stomachs (ii)
Anabaena circinalis	63.6	65.0
Chroococcus minutus	0.2	0.2
Oscillatoria schultzii	2.7	1.4
Spirulina laxissima	2.4	1.4
Spirulina platensis	10.4	24.3
Synechocystis aquatilis	4.2	2.5
Anomoneis sphaerophora	0.9	0.5
Nitzschia spp.	7.2	3.3
Gymnodinium aeruginosum	2.8	0.0

TABLE 11.60

Showing changes in proportion of intact algal units at different stages along the digestive tract of *Sarotherodon niloticus*. Proportions are percentages of total unit numbers at each stage.

Alga	Stomach	Foregut	Midgut	Hindgut	Units
Anabaena circinalis	41	8	0	0	Coils
Spirulina laxissima	39	3	1	3	Coils
Spirulina platensis	2	3	2	2	Coils
Navicula tuscula	15	72	84	74	Cells
Cyclotella meneghiniana	3	14	13	21	Cells
pH of contents	2.7	6.4	n.d.	7.6	

TABLE 11.61

Algal species commonly recorded from both plankton and stomachs of adult *Sarotherodon niloticus* in sheltered, densely vegetated littoral regions of Lake Turkana.

Dactylococcopsis raphidioides
Microcystis spp.
Phormidium mucicola

Anomoneis sphaerophora
Cymbella mulleri
Diploneis spp.
Gomphocymbella beccari
Meridion circulare
Rhopalodia gracilis
Surirella biseriata

Scenedesmus quadricauda

TABLE 11.62

Showing subjective assessments of algal frequency in the plankton (i) and stomachs of juvenile *Sarotherodon niloticus* (ii) in Allia Bay (January 1975). 3 = abundant, 2 = common, 1 = rare.

Alga	Plankton (i)	Stomachs (ii)
Anabaena circinalis	2	1
Anabaena constricta	2	1
Oscillatoria schultzii	3	1
Spirulina laxissima	3	1
Anomoneis sphaerophora	2	2
Cyclotella meneghiniana	3	3
Cymbella mulleri	3	1
Gomphocymbella beccari	2	1
Navicula cryptocephala	1	1
Navicula tuscula	1	1
Nitzschia epiphyticoides	2	1
Nitzschia palea	1	1
Rhopalodia gibba	1	1
Rhopalodia gibberula	1	1
Rhopalodia gracilis	1	1
Rhopalodia hirudiniformis	1	1
Rhopalodia ventricosa	1	1
Rhopalodia vermicularis	1	1
Scenedesmus quadricauda	1	2

TABLE 11.63

Material ingested by *Tilapia zillii* from South Island, as percentage stomach contents volume (20/6/1975).

Material	% volume
Sand	68
Anomoneis sphaerophora	31
Cymatopleura solea	
Gomphocymbella beccari	
Navicula spp.	
Nitzschia spp.	
Surirella fulleborni	
Rhopalodia spp.	
Oscillatoria spp.	1
Ostracod remnants	

TABLE 11.64

Showing the escapement of *Haplochromis macconneli* from the 38 mm stretched mesh co-end of the bottom trawl, estimated by fishing with an over-bag of 19mm stretched mesh. The number of fish of each length class retained by the 38mm cod-end is expressed as a percentage of the total fish obtained. The data were obtained from a total of 19 hauls during August and September 1973.

Length class (F.L. in mm)	% retained by 38mm cod-end	Total number recorded
20	0	10
25	18	22
30	14	35
35	11	63
40	24	68
45	37	63
50	41	85
55	54	56
60	62	61
65	58	79
70	57	87
75	72	105
80	67	170
85	73	111
90	71	65
95	80	5
100	83	6
105	-	0
110	100	2

TABLE 11.65

Distribution of Haplochromis macconneli with depth during three seasonal periods. Showing the % number of bottom trawl hauls in which H. macconneli was recorded with the total number of hauls in brackets for each depth zone. All data for the period 1972-75 have been combined.

Season	Jul - Oct		Nov - Feb		Mar - Jul		All months	
	%	No	%	No	%	No	%	No
Depth Zone (m)								
0 - 5	0	(8)	0	(6)	0	(2)	0	(16)
5 - 10	17	(18)	0	(10)	0	(12)	7	(40)
10 - 15	17	(17)	25	(12)	0	(7)	16	(36)
15 - 20	19	(21)	33	(15)	11	(9)	22	(45)
20 - 25	32	(19)	50	(14)	14	(14)	32	(47)
25 - 30	50	(10)	26	(15)	20	(10)	31	(35)
30 - 40	81	(16)	100	(9)	36	(11)	72	(36)
40 - 50	67	(6)	50	(6)	75	(8)	65	(20)
50 - 60	100	(8)	57	(7)	55	(9)	71	(24)
60 - 70	92	(12)	100	(4)	87	(8)	92	(24)
70 - 80	83	(6)	100	(1)	80	(5)	83	(12)
over 80	100	(1)	100	(2)	100	(4)	100	(7)
All								

TABLE 11.66

Haplochromis macconneli : showing the numbers of females in each gonad stage expressed as a percentage of the total number in each 4mm length group. Data combined from all sources.

T.L. (mm)	II	Gonad stage III	IV	V	Number examined
26	100	-	-	-	3
30	33	67	-	-	3
34	53	41	6	-	17
38	47	53	-	-	17
42	43	57	-	-	23
46	26	68	6	-	35
50	15	81	-	4	47
54	2	85	10	2	48
58	6	72	13	8	62
62	1	71	22	5	76
66	4	64	24	8	111
70	1	68	22	9	129
74	1	66	21	11	135
78	2	60	27	11	161
82	3	60	27	10	134
86	-	57	31	12	107
90	4	68	20	8	75
94	-	66	28	5	18
98	11	44	44	-	9
102	-	100	-	-	1
106	-	-	-	-	-
110	-	100	-	-	1
					1212

TABLE 11.67

Haplochromis macconneli: Seasonal changes in the proportion of ripe females combining monthly data from all areas and years.

Month	Number of females over 60mm T.L.		% ripe (Stage V)
January	166		11.4
February	210		12.9
March	-	no sample	-
April	359		15.9
May	135		11.1
June/July	51		15.6
August	414		11.6
September	964		15.7
October	149		25.5
November	406		18.2
December	169		7.1

TABLE 11.68

Occurrence of yolk-sac larvae of *Haplochromis macconneli* in meter townet samples

Station No	Date	Lake depth (m)	Locality	No yolk-sac larvae
206/3	18/7/74	40	4 km off North Island	15
297/24	7/11/75	30	4 km off Longech Spit	109

TABLE 11.69

Food of 47 *Haplochromis macconneli* ranging from 55 to 94mm T.L. combined from various stations in the open waters of Lake Turkana. The number of points for each food item is expressed as a percentage of the total points awarded.

Food item	% points
Unidentified prawns	74.3
Macrobrachium	3.4
Caridina	1.9
All prawns	79.6
Corixidae	0.4
Chironimid Larvae	+
Gasteropoda	1.5
Unidentified fish remains	9.9
Barbus	3.1
Haplochromis	2.9
All fish	17.8
Amorphous remains	2.2
Total number fish	47
Number stomachs with food	30
% empty	37
Total points	2569

CHAPTER 12

THE FOOD OF ZOOPLANKTIVOROUS FISHES

by
A. J. Hopson and A.J.D. Ferguson

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12. THE FOOD OF ZOOPLANKTIVOROUS FISHES

A J Hopson and A J D Ferguson

INTRODUCTION

Results from the present survey of Lake Turkana prove that rates of primary productivity are comparatively high, particularly in more northerly areas. Such high productivity is linked to correspondingly high rates of fish production only in Ferguson's Gulf (and possibly in other very localised inshore areas) where a particular combination of circumstances enables Sarotherodon niloticus to utilize fully a rich crop of blue-green algae, dominated by Anabaena circinalis and Spirulina platensis (see Chapter 2, page 123). This has resulted in phenomenally high fish yields of up to 16,000 kg/ha/year in the gulf during recent years.

Over much of the lake, however, the dominant phytoplankters Microcystis spp. were not grazed on directly by either fish or zooplankters, and food chains are linked to the primary producers by an intermediate bacterial stage involving the decomposition of algal cells. Bacteria and the detritus so formed provide the chief source of energy for much of the zooplankton, particularly the dominant copepod Tropodiaptomus banforanus. Such detritus of algal origin is constantly augmented by material derived from animal sources, including faecal matter, together with the decaying bodies of zooplankters and of the fish which form links higher in the food chain. Recycling in this way appears to be particularly thorough in the open waters of Lake Turkana, probably as a result of the vigorous wind generated pattern of circulation which tends to keep material in suspension. Relatively little detrital material accumulates on the lake bed and YURETICH (1976) comments on the remarkably low concentrations of organic carbon in the sediments. It seems likely that most of the organic carbon fixed by the primary producers is subsequently lost to the food chain during recycling, in the form of respired carbon dioxide.

Another factor contributing to the low carbon content of the bottom deposits is undoubtedly the barren nature of the coastline of Lake Turkana which, except in the region of the Omo delta, lacks extensive areas of fringing swamp. These are a characteristic feature of most major African lakes in which debris from macrophytic swamp vegetation may be carried well offshore before sinking to the bottom and becoming incorporated in the sediments. The generally low offshore densities of oligochaetes, ostracods, chironomid larvae and molluscs, which constitute the benthic fauna of Lake Turkana are certainly correlated with the dearth of organic material on the bottom.

Under the circumstances outlined above, the zooplankton clearly fulfils an unusually important function in the food chains of the open waters of Lake Turkana. The purpose of the present study is to investigate the role of zooplankton in the diet of various fish, mainly species of small size, occurring in both inshore and offshore habitats:

Species	Habitat
Alestes nurse	inshore
A. minutus	offshore
A. ferox	offshore
Micralestes acutidens	inshore and offshore
Barbus turkanae	offshore
Barilius niloticus	inshore
Engraulicypris stellae	inshore and offshore
Chelaethiops bibie	inshore and offshore
Aplocheilichthys rudolfianus	inshore
Early stages of Lates spp.	inshore and offshore
Haplochromis rudolfianus	inshore

In addition to the above species which are studied in detail in the present section, zooplankton featured prominently in the food of several other species of fish considered in previous sections of this work. They include Alestes baremose (Chapter 9, page 783), the juvenile stages of Hydrocynus forskalii and three siluriform fish, Chrysichthys auratus, Clarias lazera and Synodontis schall (Chapter 10, pages 1046, 1047 and 1076 respectively.

Diel changes in feeding behaviour have been investigated wherever possible and the results have been interpreted in the light of data on vertical migrations in both prey and predator species. Prey selectivity has also been examined, both in situations where two or more forms compete intraspecifically and in cases where dietary changes occur during the ontogeny of a particular species. In a number of instances, direct comparison is possible between data from several species of fish collected together during the same diel series of samples.

For most of the species investigated, material was obtained from a number of different localities, often varying considerably in environmental character. It has often been possible to relate local changes in diet with the observed pattern of horizontal zooplankton distribution detailed in Chapter 3. At times, the food data have corroborated evidence obtained during the plankton survey, as for example the indications of a seasonal population crash in the zooplankton of the Northern Sector during the flood period. This was reflected in a high proportion of nearly empty stomachs in several species of zooplanktivorous fish from the same area, with fish scales forming much of the scant food-intake, an indication of severe food shortage. The above fall in zooplankton concentrations almost certainly resulted from the influx of sediment-rich floodwater into the northern fringe of the lake. In many cases, however, it is believed that temporal and spatial fluctuations in zooplankton densities in Lake Turkana resulted from the effects of heavy predation, often localised. Such trophodynamic relationships are considered in the final discussion.

METHODS

Inshore samples were usually caught with a foot-seine of mosquito netting up to a distance of ca 6 m from the large margin. Offshore samples were obtained either with a metre townet or the frame trawl. All material was stored in 5% formalin for subsequent examination in the laboratory. In fish over ca 3.5 cm in length an incision was made in the wall of the body cavity as an aid to preservation.

A volumetric method based on HYNES (1950) was usually employed to record the composition of the food. The fullness of the stomach was first estimated on a percentage basis from 0%-empty to 100%-full and the contents were sorted in a Bugarov tray. The proportion of each item was then estimated as a percentage of the total food present. A number of points was awarded to each food item by multiplying its percentage contribution by the percentage fullness of the stomach. The maximum possible number of points scorable in a single stomach was thus 10,000.

Apart from several early samples, Cladocera and Copepoda were identified to species but usually no distinction was made between copepodite and adult stages. Copepod nauplii were treated as a separate category. However, in a few samples involving Alestes minutus, Micralestes acutidens, Engraulicypris stellae and the early stages of Lates spp., a more detailed examination of food selectivity was made and in addition to the usual recording method, a complete count was made of the contents of each stomach in a Sedgewick-Rafter cell. The numbers of nauplii, copepodites, males and females were recorded for each species of copepod. Immature and adult cladocerans were also counted separately.

Food analyses of the 11 species investigated appear in Tables 12.1-17. In all cases the total number of points recorded for each food item has been expressed as a percentage of the maximum number of points for a particular sample. Using these values, the importance of a food item in absolute terms may be compared directly from sample to sample. The number of points for individual items is also expressed (in brackets) as a percentage of the total number of points actually scored in a sample. This value indicates the importance of a food item in the sample relative to other food items.

SAMPLING SITES

Much of the material on which the present study is based was obtained from two stations, Met Bay and Lodge Bay on the east shore of Ferguson's Gulf near the tip of Longech Spit. although separated by only 1.5 km, evidence provided in Chapters 1, 2 and 3 indicates that they differed considerably, both limnologically and in the composition of the plankton.

Met Bay lay within the main body of gulf water with dense populations of the blue-green algae Anabaena and Spirulina. The dominant zooplankter was Mesocyclops leuckarti, and Tropodiaptomus banforanus was usually absent from this area. The shoreline was generally sandy with a scattered cover of partly submerged grass (Sporabolus spicatus), shelving relatively steeply to soft mud at a depth of 1-1.5 m.

Lodge Bay was situated at the entrance to Ferguson's Gulf and lay within the main water body of the open lake, with the zooplankton dominated by T. banforanus. Algal densities were always much lower than in the actual gulf, with Microcystis flos-aquae usually the principal species. The substrate was similar to that of Met Bay, but a three metre wide zone of submerged Potamogeton pectinatus formed a moderately dense belt of vegetation at a depth of ca 1-2 m. Brief notes on other inshore sampling stations are as follows:

Todenyang: profile very flat, substrate muddy sand, vegetation chiefly emergent grasses with occasional patches of Typha.

Kakoi: profile moderate, substrate sand and basalt boulders with thinly scattered grasses.

Crater Bay, Central Island: profile moderate to steep, substrate gravel bordered with rocky outcrops, no macrophytic vegetation but moderate growth aufwuchs on rock surfaces.

Ballo: profile slight, substrate sand and shingle, no vegetation.

South Island: profile moderate, substrate smooth flat rock interspersed with stones and gravel, no macrophytic vegetation but slight growth aufwuchs on rock surfaces.

RESULTS

(a) Alestes nurse

Data for this inshore species are restricted to a single diel study carried out at Longech (Table 12.1). A marked change in behaviour is evident after dark, with fish virtually absent from the Lodge Bay Station during the night. Supplementary material was obtained at 21.45 hrs from a larger beach seine at Met Bay which sampled up to 75 m offshore, but at 03.15 hrs no A. nurse were recorded at either site. The results indicate a nocturnal migration offshore followed by a rapid return to the marginal areas of the lake at dawn when the species was again common in Lodge Bay (Table 12.1). During the hours of daylight the diet in Lodge Bay was dominated by Tropodiaptomus banforanus. Nocturnal feeding in these fish clearly followed a different pattern and the dawn sample had fed chiefly on corixids. Insects were also important in the 21.45 hrs sample from Met Bay with chironomid pupae forming 87% of the food.

Diel variations in the volume of the food intake are difficult to assess from the present results since there was an interval of over 10 hours between the dawn and dusk samples from Lodge Bay (disregarding the 21.00 hr sample when only 1 fish was caught). Feeding activity clearly persisted during the hours of darkness, but the lower values of percentage fullness recorded from Met Bay at 21.45 hrs and from Lodge Bay at dawn suggest that either the intensity of predation was lower or that insects were more difficult to catch. The absence of Tropodiaptomus banforanus from the food of A. nurse during the night is also open to a variety of interpretations. It seems unlikely that nocturnal migrations of prey and predator led to physical separation, and a change of feeding strategy under conditions of reduced illumination is the most satisfactory explanation.

(b) Alestes minutus

Results from a diel study of the food of A. minutus in the open lake off Longech Spit are presented in Table 12.2. The relatively low values of stomach fullness recorded throughout the 24 hour cycle probably indicate an overall food shortage rather than low feeding intensity. Changes in the proportion of the various zooplankters which always formed a high percentage of the food may be correlated satisfactorily with the vertical migration patterns of predator and prey. During the hours of daylight A. minutus was confined to the midwater scattering layer at a depth of 12-20 m. Cladocera, which reached peak abundance in this depth zone (see Chapter 3, page 192), formed a moderately high proportion of the food. With the onset of darkness, A. minutus migrated upwards and dispersed over the top 12 metres. The proportion of Cladocera in the food fell drastically and in the early hours of the morning, Tropodiaptomus banforanus was the dominant food item. The proportion of T. banforanus was still very high after dawn when A. minutus had already migrated downwards into the midwater layer, but by 11.48 hrs the intake of Cladocera was similar to that recorded during the previous afternoon (Table 12.2).

Food analyses from various localities are presented in Table 12.3. The results are in general agreement with the diel data and indicate that zooplankton, particularly the dominant openwater species T. banforanus, provides the bulk of the food requirements of A. minutus. Small fish and prawns at times supplemented the diet but insects were generally rare. With the exception of material from the open lake near Koobi Fora (Table 12.3) the stomachs contained comparatively little food and an entire sample of fish caught in the Longech area during July 1975 were empty. As suggested previously the low content of the stomachs was probably due to food shortage. This view is supported by the presence of fish scales in the gut contents of a significant number of A. minutus from three of the sampling stations (Table 12.3). The scales were never accompanied by other fish remains and appear to have been selected individually either from the bodies of other fish or from suspension in the water column. Scale eating was also recorded in Micralestes acutidens and Chelaethiops bibie from the same sampling stations in the Ilaret area during August 1975 (see Tables 12.6 and 12.13). It is known that in previous years zooplankton populations were reduced to a minimum in the early part of the flood season and it seems likely that this is a regular annual event.

Although the above results show the species composition of the food of A. minutus to be similar to that of the openwater zooplankton, more detailed analyses have demonstrated that the size and developmental stage of the prey species selected tends to change with the size of the fish. Thus in the sample from Station 281/14 (Table 12.3) with A. minutus ranging from 12-31 mm FL, several interesting trends are evident. Tropodiaptomus banforanus formed from 50% to 90% of the total number of zooplankters found in individual stomachs, but nauplii of this species were only ingested by fish up to 18 mm FL. The percentage of adults among T. banforanus in the food increased with the size of the predator from 28% in 14 mm fish to 97% in A. minutus of 31 mm FL (Fig. 12.1). In the plankton, adults rarely formed more than 30% of the total T. banforanus population and predation by the largest A. minutus was highly selective towards mture individuals.

A similar situation was observed in the case of Mesocyclops leuckarti where the proportion of adults taken by A. minutus rose from 28% in fish of 17 mm to 68% at a length of 24 mm.

Although A. minutus fed selectively with regard to prey size, the proportion of the different species of copepods and cladocera in the food was similar to that in the plankton. No marked preferences for particular zooplankton prey species are evident.

(c) Alestes ferox

Diel changes in the food of A. ferox are demonstrated in Table 12.4. The material was collected from the same samples as the A. minutus considered in Table 12.2 above.

Results (Table 12.4) indicate a varied diet in A. ferox including zooplanktons, prawns, insects and fish. This species undergoes a similar pattern of diurnal vertical migration to A. minutus and it is interesting to note that in the afternoon samples Cladocera feature prominently in the food of both species. In A. ferox, however, Cladocera declined steadily in importance and failed to become re-established as a food item the following day. Changes in relative importance of Tropodiaptomus banforanus resembled the diel pattern observed in A. minutus, with peak concentrations occurring at dawn when the copepod formed a major part of the food of A. ferox (Table 12.4). Prawns were taken during the afternoon and reached a peak during the early hours of darkness. They were virtually absent in the food from dawn onwards when adult chironomids became a dominant category of prey. The chironomids were probably freshly emerging imagos. Fish were recorded throughout the sampling period but reached a peak in the night time samples when Alestes minutus was the dominant prey species. The presence of fish scales is of no particular significance in the case of A. ferox since residual scales often remain in the stomachs of predatory fish after fish prey has been digested. The results indicate that feeding activity increased after dark and peak stomach fullness was recorded during the night and dawn samples when fish and T. banforanus respectively were the dominant food items.

Analyses of the food of A. ferox from various other samples in the Longech and Namadak area of the lake are presented together with the combined results from the diel study in Table 12.5. Fish tended to dominate food in the supplementary samples and in two cases Alestes minutus was again a major prey species. Engraulicypris stellae formed a high proportion of food in the large sample of A. ferox from Station 109/1 (Table 12.5). Prawns, principally Macrobrachium niloticum were clearly an important food item forming a peak of 39% of the diet at Station 282/2. Zooplankton was, however, generally less frequent than in the diel study although T. banforanus featured prominently at Station 121/2.

The size of A. ferox examined during the present study ranged from 2.8 to 12.0 cm FL, but relatively little variation in diet with increasing size was noted. Zooplankton thus occurred regularly in the food of fish approaching maximum length.

(d) Micralestes acutidens

Analyses of the food of M. acutidens from various localities appear in Table 12.6. Marked differences are apparent between inshore samples from the Longech area in the Central Sector and from stations both inshore and offshire in the Northern Sector.

The Longech material was obtained from Lodge Bay and the daytime sample included two size groups of M. acutidens, the food of which has been analysed separately. Zooplankton formed the bulk of the stomach contents in both size groups, but whereas the smaller fish fed principally on cladocerans and ostracods, the larger fish had ingested chiefly Tropodiaptomus banforanus. Insects were a minor food component in the diurnal samples, but the presence of a high proportion of chironomid larvae in the stomachs of two fish caught at 21.30 hrs on 6.3.75 (Table 12.6) indicates that, as in other species, insect food may increase in importance after dark.

The food of M. acutidens from the Northern Sector of the lake, including a high proportion of the blue-green alga Microcystis flos-aquae, differed strikingly from that of fish in the Longech area (Table 12.6). A change in the colour of the alga from green to brown in the more posterior section of the gut indicates that the material was at least partially digested. The ingestion of Microcystis in quantity by fish is a comparatively rare phenomenon which has not been recorded previously in Micralestes spp. FISH (1951) considered that Microcystis together with other blue-green algae, was indigestable to Tilapia spp. and it was widely believed that this applied to fish in general. However, MORIARTY and MORIARTY (1973) have shown that Sarotherodon niloticus in Lake George successfully assimilate a high proportion of ingested Microcystis.

Evidence from the present studies indicates that M. acutidens selected Microcystis only when the more usual sources of zooplankton food were in short supply. Gut analyses of Alestes minutus and Chelaethiops bibie obtained during cruise 274 from the same offshore stations as M. acutidens (Tables 12.3 and 12.13) both indicate a pronounced dearth of food and as mentioned above, a significant proportion of fish had ingested scales. It will be seen from Table 12.6 that scale-eating (which is considered to be a sign of food shortage) also occurred in M. acutidens. The use of Microcystis as a major food source was not observed in other Lake Turkana fish.

A more detailed examination of the zooplanktonic food of five M. acutidens ranging from 2.9 to 3.4 cm FL, caught at Station 274/5 indicates that this species was less selective than Alestes minutus of similar size. Thus in M. acutidens the relatively high proportion of nauplii and copepodites of Tropodiaptomus banforanus and Mesocyclops leuckarti occurring in the diet corresponded closely to the proportions observed in zooplankton populations whereas Alestes minutus tended to select mature copepods.

(e) Barbus turkanae

Unlike the other offshore species under review, B. turkanae has proved to be a demersal species living on or near the bottom in deeper water throughout the lake. Analyses of gut contents from various localities (Table 12.7) show that although zooplankton featured regularly in the diet, it proved only a very small proportion of the total intake. The food was chiefly benthic in origin with ostracods generally the principal and most widespread prey category. Chironomid larvae were also important food items and molluscs had been ingested at two out of the six sampling sites. Naucorids and prawns each predominated at one of the localities, showing that B. turkanae were also capable of capturing larger and more mobile forms of prey.

The pattern of distribution in B. turkanae is similar to that of a small demersal deepwater cichlid, Haplochromis macconneli, the food of which has been analysed elsewhere in this report (see Chapter 11, Table 11.69). Small invertebrates living on or near the bottom also formed the principal food of the cichlid, but a much higher proportion of prawns were eaten and ostracods were apparently avoided. The feeding habits of *B. turkanae* more closely resemble those of a much larger congener, *B. bynni*, which has a demersal distribution extending both inshore and offshore. The food of *B. bynni* (see Chapter 9, page 825) was principally benthic and ostracods were a particularly important prey category in deeper offshore areas.

(f) *Barilius niloticus*

Diel changes in the food of *B. niloticus* are presented in Table 12.8. The data from the shore of Crater Bay, Central Island, have been separated into two classes on the basis of size: smaller fish of 10-22 mm FL and larger fish of 3-52 mm FL. Clear differences are evident in both the composition of the food and diel feeding patterns in the two groups.

The evidence (Table 12.8) suggests that during the initial noon sampling period, the smaller fish were feeding on the bottom with ostracods, harpacticoids and sessile diatoms forming most of the food intake. During the afternoon and evening, the smaller fish appear to have moved off the bottom to feed on planktonic forms, particularly copepod nauplii. More advanced stages of copepods were also included in the food, with *Mesocyclops leuckarti* becoming particularly common at dusk. Throughout the early sampling periods stomachs remained on average approximately half full. Feeding appears to have ceased after dark, and all five individuals caught at midnight were empty. Activity recommenced at dawn, but at 06.30 hrs the stomachs still contained very little food. Unfortunately, one small fish was caught during the final sampling period, and the significance of the high proportion of insects in both this and the previous sampling period is uncertain, although peak proportions of insects were recorded in the corresponding samples of larger fish.

Diatoms and blue-green alga, which form aufwuchs communities on rock surfaces in Crater Bay, dominated the food of larger fish in the noon sample. Insects, particularly terrestrial forms, were also relatively important. As in the smaller fish, there was a dramatic shift to planktonic food during the afternoon period, with *Mesocyclops leuckarti* forming over 80% of the intake. Nauplii were not observed in the stomachs of larger fish, indicating marked size discrimination in favour of larger prey. The incidence of insect food increased noticeably from dusk onwards, with a corresponding decline in *M. leuckarti*. At midnight, 42% of the food consisted of newly emerged chironomids caught on the surface. The prawn *Caridina nilotica*, which migrates upwards from deep water after dark, made a significant contribution to the diet at midnight. Peak proportions of insect food occurred in the dawn sample when Ephemeroptera, particularly chloeonid nymphs, formed the bulk of the food. Chironomid larvae were the most important prey category in the mid morning sample.

The results show that feeding activity in the larger fish continued day and night with comparatively rapid changes in prey selectivity. Peak values of percentage fullness were recorded at midnight and at dawn when insect food predominated, but a relatively high value was also obtained for the midday sample during a phase of algal feeding. Insect food was clearly plentiful in the sampling area but was comparatively little utilised by the smaller fish, probably as a result of physical size limitations.

Food analyses for various inshore localities are presented in Table 12.9. The results differ considerably from those obtained during the diel study (Table 12.8) with the cladoceran *Diaphanosoma excisum* occurring as the dominant food item at three widely scattered localities, Kakoi, Ballo and South Island. The low incidence of insect food at the three stations may have been a temporal effect since the samples were all diurnal and, as shown in Table 12.8, zooplankton was the chief prey category at Central Island during the afternoon, with insects increasing in importance later in the day. The comparative rarity of *Tropodiaptomus banforanus*, the dominant zooplankter of the open lake, in the food of *B. niloticus* is worthy of comment. This copepod was recorded in net samples at nearly all inshore stations during the shore survey. It seems unlikely that the species is avoided on account of its comparatively large size and its absence from the diet is difficult to explain.

Two size groups of *B. niloticus* were represented in the sample from Kakoi. Food analyses (Table 12.9) show that unlike the Central Island sample the composition of the diet was almost identical, with *D. excisum* predominating in each case.

(g) *Engraulicypris stellae*

Diel changes in the food of inshore *E. stellae* at Met Bay are shown in Table 12.10. There was a striking change from a diet consisting entirely of the copepod *Mesocyclops leuckarti* during the daytime to a fully insectivorous regime, dominated by chironomids, at night. The selection of chironomids started during the late afternoon with larvae and pupae taken in equal proportions. Pupal chironomids, probably caught during a migration to the surface prior to emergence, became increasingly common after dark and reached a peak at dawn. By 10.30 am, *E. stellae* had reverted to *M. leuckarti*, the dominant zooplankter in the confined waters of Ferguson's Gulf. Data from a sample collected from Lodge Bay at approximately the same time as the final Met Bay sample are also included in Table 12.10. Although the Lodge Bay fish were also wholly zooplanktivorous, notable differences from the Met Bay results are evident, and the dominance of *Tropodiaptomus banforanus* is characteristic of plankton of the open lake.

The results show that feeding continued in *E. stellae* throughout the 24 hour cycle but the values of percentage fullness, highest at 12.30 hrs, indicate peak activity during the middle of the day when *M. leuckarti* was the principal food.

Data from an abridged diel study of feeding in offshore *E. stellae* are presented in Table 12.11. The prey was entirely zooplanktonic (if small *Caridina nilotica* may be included in this category), but changes in food selectivity are evident, with *Tropodiaptomus banforanus* predominant at 19.15 hrs just after dusk, and *Diaphanosoma excisum* forming the chief item of prey in the morning at 08.15 hrs. It is impossible to correlate these changes with the vertical migrations of the prey species concerned since the *E. stellae* were obtained from oblique metre townet hauls which sampled the entire water column. The results do, however, indicate a definite fall in feeding intensity during the night which, as discussed below, may be characteristic of many forms with a diet restricted entirely to zooplankton.

Summaries of the results reviewed above have been combined with data on the food of *E. stellae* from other localities in Table 12.12.

Zooplankton was the principal category of food in all diurnal observations. Data from two successive inshore samples at Station H3, Central Island (Table 12.12), however, indicate a similar trend after dark to that observed in Met Bay (Table 12.10), with a change from *Mesocylops leuckarti* at 18.40 hrs to a majority of chironomid adults in the diet at midnight.

Although as discussed previously, *Tropodiaptomus banforanus* was the chief prey species in both the Lodge Bay (Table 12.10) and the diel Central Island (Table 12.11) samples, evidence from open water stations indicates that *M. leuckarti* was often selected in preference to the more abundant but larger calanoid. This is particularly well illustrated in data from Station 203/33 which have been analysed separately for two size classes of *E. stellae* (Table 12.12). Even in the larger size class, the number of points scored by *M. leuckarti* was nearly double that of *T. banforanus*, and the difference was greater in the smaller size class. Results from Station 203/33 also show that a minor proportion of planktonic diatoms, particularly *Surirella*, was included in the diet of fish of 14-18 mm FL. Planktonic diatoms constituted the sole food intake of *E. stellae* up to a length of ca 9 mm when the young fish started to supplement their diet with nauplii.

The low values of stomach fullness recorded from three openwater diurnal stations during cruise 242 on a transect from Longech Spit to Allia Bay (Table 12.12) may indicate shortage of food over a wide area of the lake at the time of sampling in February 1975.

(h) *Chelaethiops bibie*

Analyses of the food of *C. bibie*, a species confined to the northern part of the lake, are presented in Table 12.13. It is evident that the overall importance of zooplankton was low compared with most of the species under review. However, the two open water samples (Stations 274/6-7) were collected together with *Alestes minutus* and *Micralestes acutidens* in an area where, it is believed, zooplankton densities were seasonally very low. As a result, the diet of both small characins proved to be atypical (see above) particularly with regard to the high incidence of fish scales occurring in the stomachs. Fish scales were also frequent in the food of *C. bibie* (Table 12.13) and it seems likely that the feeding behaviour of this species was also affected by food shortage. Under normal circumstances it is possible that a higher proportion of zooplankton is consumed.

Considering the results as a whole, insects formed the dominant category of food, with chironomids particularly important in the inshore sample. The incidence of allochthonous food including grass seeds, macrophytic fragments and terrestrial insects was comparatively high in this species. A minor but significant proportion of *Microcystis* was included in the diet at Station 274/7 but it is not known if the blue-green alga was successfully assimilated by *C. bibie*.

(i) *Aplocheilichthys rudolfianus*

The limited data on the food of this small inshore species are analysed in Table 12.14. The results indicate that *A. rudolfianus* preys entirely on zooplankton. Feeding appears to be unselective and *Tropodiaptomus banforanus*, the dominant zooplankter of the open lake, also predominates in the food.

(j) Early stages of Lates spp.

As mentioned previously, it was impossible to separate the early stages of Lates niloticus and L. longispinis amd the material now under consideration, including post larvae and early juveniles up to 37 mm TL, probably contains examples of both species. Post larval Lates of up to ca 15 mm TL are pelagic in distribution occurring throughout the open waters of the lake. Young Lates start to move inshore at a length of 10-12 mm TL and juvenile fish of ca 15 mm and above live in shallow water close inshore.

An analysis of diel changes in the food of juvenile Lates in Lodge Bay, at the mouth of Ferguson's Gulf, is presented in Table 12.15. The results show that the young Lates were diurnal feéders with peak activity in the middle of the day, and percentage fullness decreasing steadily through the afternoon and evening. The stomachs had thus become completely empty by the early hours of the morning. Feeding activity recommenced at dawn and by 10.15 hrs the percentage fullness had risen to 77%.

The composition of the food was varied and included zooplankton and fish, together with a smaller proportion of insects (principally corixids) and prawns. Tropodiaptomus banforanus was the most important prey species and always formed the highest proportion of food at times when the stomachs were relatively full. As in Aplocheilichthys rudolfianus the similarity between the proportion of zooplankton species in the food and in the open lake indicates that Lates were unselective with regard to this category of prey. It is interesting to note that in the dawn sample predation was restricted to larger items such as fish and corixids which probably provided a strong visual stimulus. Heavy feeding on zooplankton indicated by the 10.15 hrs sample appears to have been delayed until conditions of full daylight prevailed.

Combined results from the diel study are compared with data from two further samples in Table 12.16. The food of early juvenile fish from a daytime sample in Lodge Bay collected during May 1974 is shown in the first column. The relatively broad spectrum of food, including insects and fish in addition to zooplankton, is similar to that observed in the diel samples from the same locality. However, the two series differ considerably in the composition of the zooplankton prey and Mesocyclops leuckarti had clearly replaced Tropodiaptomus banforanus as the principal food item in the May 1974 samples. The predominance of M. leuckarti suggests that during May 1974 gulf water had temporarily advanced into Lodge Bay with an accompanying change in the planktonic fauna. This view is supported by the inclusion in the food of Afrocyclops gibsoni, a rare species which, in the Central Sector of the lake, is chiefly confined to Ferguson's Gulf.

Post larval food is also analysed in Table 12.16 where a sample from Station 281/4A in the open waters of the Northern Sector has been subdivided into two size-classes, 4-8 mm and 8-12 mm TL. Differences between the two groups, both of which had fed exclusively on zooplankton, are relatively slight. The smaller fish had ingested a somewhat higher proportion of Cladocera and less T. banforanus. In spite of the comparatively small size of the Lates post-larvae, the species composition of zooplankton in the food was similar to that observed in the open lake and, as in the early juvenile fish, relatively little prey discrimination appears to have been exercised.

(k) Haplochromis rudolfianus

Results of a diel study of the food of H. rudolfianus from Lodge Bay are shown in Table 12.17. The material was obtained in the same foot seine hauls as the juvenile Lates (Table 12.15). Unfortunately the species was comparatively rare in the study area and samples are too small for a confident assessment of the diel feeding pattern to tbe made. The data show that H. rudolfianus was principally a benthic feeder with a varied selection of insects forming a high proportion of the diet, and with ostracods also occurring regularly. Planktonic forms are relatively uncommon, with the exception of the final mid-morning sample, when Tropodiaptomus banforanus formed 39% of the total food intake.

Feeding activity appeared to be greatest in the middle of the day, declining to a minimum at night, but more data are required to confirm this pattern.

DISCUSSION

The introductory remarks have drawn attention to the under-utilization of phytoplankton resources by fish in the open waters of Lake Turkana, and to the poverty of the benthic fauna. The present study shows that in consequence zooplankton plays an unusually important role in the diet of a high proportion of fish, chiefly species of small adult size, but also young and more rarely adults of larger species. Trophic relationships proved to be complex with at least six species feeding competitively on zooplankton in the open lake. The results indicate that resource partitioning was accomplished in four different ways:

(i) spatial separation of competitive species achieved by differences in vertical and horizontal distribution and by diel migrations;

(ii) interspecific differences in size selectivity;

(iii) interspecific differences in diel feeding patterns;

(iv) ontogenetic changes in diet. The last of these tended to reduce intraspecific competition.

Observations in the offshore waters of Lake Turkana showed that during the day, marked vertical zonation resulted in the segregation of three groups of zooplanktivorous fish. In the surface layers Alestes baremose fed principally on adult zooplankters (see Chapter 9, page 784), particularly Tropodiaptomus banforanus, while post larval Engraulicypris stellae ingested copepod nauplii and diatoms. At intermediate depths, in the midwater scattering layer, two species of small Alestes coexisted but whereas the diet of A. minutus was chiefly restricted to zooplankton, A. ferox preyed on small fish (including A. minutus) and prawns in addition to planktonic crustacea. Adult Engraulicypris stellae (which fed almost entirely on zooplankton) were scattered over the entire water column between the midwater scattering layer and the bottom during the daytime. In contrast, Lates spp. post larvae ranged throughout the 30 metres of the water column and thus overlapped in distribution with each of the preceding species. Synodontis schall with a varied diet including fish, prawns and molluscs (see Chapter 10, page 1076) at times fed exclusively on zooplankton and was distributed throughout the water column at all depths.

Considerable changes in the distribution of pelagic fish occurred after dark, with *Alestes minutus* and *A. ferox* migrating upwards into the superficial layers. Diel changes in feeding intensity were also noted. *Lates* post larvae and *Alestes baremose* are diurnal feeders in which food intake fell to a minimum after dark whereas *Synodontis schall* was principally a nocturnal feeder. Relatively little difference between day and night was noted in the two small species of *Alestes* although the composition of the food changed considerably. Thus Cladocera featured prominently in the food of *A. minutus* by day whereas *Tropodiaptomus banforanus*, the principal zooplankter in the surface layers, was eaten almost exclusively at night. In *A. ferox* a succession of dietary changes were noted involving fish, prawns, insects and *T. banforanus*, the latter becoming the predominant food item at dawn. The results suggest that vertical migrations provided the two small species of *Alestes* with a mechanism by which peak concentrations of prey species might be systematically located within the water column. The resultant increase in the variety of potential food would have an obvious survival value in situations where particular prey species were likely to become periodically depleted.

Size selectivity of prey varied both within and between species. In *A. minutus* the smallest fish of 12 mm FL fed on all stages of copepods but the proportion of nauplii and copepodites in the diet fell steadily with increasing size. Ontogenetic changes were even more pronounced in *Engraulicypris stellae* where the smallest size groups fed entirely on diatoms, augmenting their diet with nauplii at a length of ca 11 mm and feeding regularly on adults only from a length of 20 mm and upwards. *Lates* post larvae showed no such changes in size preference but tended to feed exclusively on adult copepods from a minimum observed length of 6 mm. The numbers of copepods ingested per stomach increased with the size of the predator.

The number of fish species feeding on small invertebrates was higher in marginal areas of the lake than in the openwater. Insects also increased in abundance inshore but zooplankton remained a common food category in most species. Despite the increased species diversity inshore, interspecific competition in fish was reduced by differences in feeding behaviour. On the basis of diet, four main categories are recognisable among the inshore species investigated during the present study:

(i) those feeding predominantly on zooplankton.

(ii) those feeding mainly on zooplankton during the day but switching to insects at night.

(iii) benthic feeders which also utilised a small proportion of zooplankton particularly during the hours of daylight.

(iv) fish feeding exclusively on benthic forms.

Interspecific competition among the inshore forms was also decreased by variations in the diel feeding cycle and by differences in habitat preference.

Aplocheilichthys rudolfianus and small *Barilius niloticus* of under 22 mm FL fed exclusively on zooplankton and in the latter species feeding activity was shown to be restricted to the hours of daylight. Juvenile *Lates* spp. of 22-37 mm TL were also mainly zooplanktivorous and followed a similar diurnal feeding pattern. It is interesting to note that several species with a mixed diet including *Alestes nurse*, large *Barilius niloticus* and inshore *Engraulicypris stellae*, likewise preyed on plankton during the day but changed to insect food after dark. It is apparent that there was a general tendency for zooplankters to be avoided at night by all the small inshore species under review. There is no evidence to suggest that the copepods and cladocerans involved migrated away from the shore, at least during the early part of the night when calm conditions usually prevailed. It was noted that in the Met Bay study area *Clarias lazera*, a filter feeder, ingested large numbers of *Mesocyclops leuckarti* during the hours of darkness Possibly the small inshore species were visual feeders conditioned to high diurnal light intensities and when the smaller planktonic forms became more difficult to discriminate after dark, feeding either changed to larger insect prey or ceased altogether. Diel changes in the availability of insect food were probably not responsible for the observed switch and although certain forms, particularly emerging chironomids, were more readily captured at night, benthic feeders such as *Haplochromis rudolfianus* preyed successfully on insects during the day.

As with offshore fish, subtle differences in prey size selectivity were observed in inshore species. Thus adult *Micralestes acutidens* were less size-selective with regard to zooplankton than other species at comparable length, and ingested a relatively high proportion of nauplii. *Micralestes acutidens* was also the only planktonic feeder under investigation which at times of food shortage ingested the blue-green alga *Microcystis* in large quantities.

In certain cases spatial separation of potentially competitive species resulted from differences in substrate preference. For example, *Chelaethiops bibie* was restricted to soft substrates in the north part of the lake whereas *Barilius niloticus* predominated on hard substrates to the south. The two species overlapped on the high energy beaches of the west coast north of Ferguson's Gulf where environmental conditions were relatively unstable. The exclusion of *C. bibie* from patches of soft substrate which often formed in the shelter of bays in more southerly areas, may have been due to their relative isolation, but competitive exclusion cannot be ruled out. *Barilius niloticus* extended over both hard and soft substrates on shorelines where hard substrates predominated.

Results from other major African lakes where marginal vegetation is often well developed, suggest that zooplankton usually plays a less important role in the major food chains involving fish. FRYER and ILES (1972) noted that zooplankton is very sparse in Lake Malawi and although a species flock of zooplankton-eating cichlids, the 'Utaka' has evolved, they are localised in distribution. Offshore zooplankton populations were regularly exploited by only a single pelagic form, the young of *Engraulicypris sardella*. In a study of the non-cichlid fish of Lake Victoria (CORBET, 1961) *Engraulicypris argenteus*, a pelagic species, was the sole zooplanktivorous fish recorded. Planktonic crustacea were absent from the diet of numerous inshore and demersal fish which fed on invertebrate food. Although there is a possibility that some of the many cichlid species occurring in Lake Victoria feed on zooplankton, it would appear that insects and other invertebrates groups are usually of much greater importance in the diet of fish.

Results from Lakes Chad and Tanganyika prove that, as in Lake Turkana, zooplanktivorous fish are an essential link in openwater food chains. Data provided by ROBINSON and ROBINSON (1972) show that *Alestes dageti* and *Micralestes acutidens*, the dominant species of small pelagic fish in Lake Chad, had similar feeding habits to small characins in Lake Turkana. *Microcystis* was not observed in the food of the Lake Chad population of *M. acutidens* but there was no evidence to show that other forms of food were in short supply. *Engraulicypris minutus* and two clupeids, *Limnothrissa miodon* and *Stolonothrissa tanganyikae*, are the principal zooplanktivorous fish in Lake Tanganyika (COULTER, 1970). The clupeids form dense shoals which occur throughout the open waters in a pattern analogous to the distribution of *A. minutus* and *A. ferox* in Lake Turkana.

Previous work on populations of fish in African lakes has indicated that food is not usually an important factor regulating the numbers and distribution of fish. FRYER and ILES (1972) regarded food as superabundant on rocky shores in Lake Malawi where numerous species often shared a similar food resource. They considered that predation by larger fish was a more important factor for population control and a factor which also reduced the effects of competition between the prey species of fish. CORBET (1961) and CARMOUZE *et al* (1972) reached similar conclusions concerning the importance of food in Lakes Victoria and Chad respectively.

The widespread incidence of zooplankton in the diet of fish in Lake Turkana suggests a generally low level of interspecific competition. As mentioned previously this may be assisted by resource partitioning resulting from differences in feeding behaviour and distribution. However, there is strong evidence to show that in Lake Turkana the zooplankton was at times subject to relatively high predation pressure, particularly the later stages of Crustacea. When pelagic fish, particularly *Alestes minutus*, concentrated seasonally in the Northern Sector of the lake during the flood period, populations of zooplankters in the same area crashed. It is considered that the decimation of the zooplankton was due to a combination of adverse affects of high silt load in the turbid flood waters, and heavy predation by fish. The affects of food shortage were evident in the unusual diet of fish from the area. A significant proportion of *Alestes minutus* and *Chelaethiops bibie* had ingested fish scales and *Micralestes acutidens*, while also eating fish scales, had fed chiefly on *Microcystis* colonies.

Echo surveys (Chapter 8, page 648) have demonstrated that over a considerable area of the lake stretching from south of Kerio Bay to the vicinity of North Island, pelagic fish, chiefly *A. minutus* and *A. ferox*, tended to concentrate heavily in a zone near the west shore situated between the 10 and 30 metre contours. Densities of pelagic fish fell considerably from west to east across the lake. Zooplankton studies showed that the reverse situation was true of planktonic crustaceans with high densities near the east shore (Chapter 3, Figs. 3.55-3.62), indicating that heavy predation in the concentrations of fish had reduced population densities in the prey species. The basic pattern of distribution of pelagic fish showed no marked seasonal change, and the failure of the shoals to move into adjacent areas of the lake where zooplankton densities were higher suggested that food resources were adequate.

The key to this somewhat paradoxical situation is thought to be the strong prevailing south easterly winds which are of almost daily occurrence. The winds are strong enough to generate surface currents to a depth of ca 6 m which transport a considerable body of water towards the west shore. Compensatory currents towards the east shore follow the lake bed. Zooplankters are thus constantly carried towards the west shore with the result that populations in areas of high fish density are constantly replenished. Since zooplankters tend to concentrate in the top 30 metres, movement towards the east shore in the return currents would be negligible. The hypothesis is supported by evidence on the vertical migrations of *Tropodiaptomus banforanus* and *Mesocyclops leuckarti* in which a downward movement was shown to occur as a response to increased wind and wave action (see Chapter 1, page 28). This is viewed as an adaptation to counter the effects of downwind drift. With regard to pelagic fish distribution, an analogous situation has been noted in Lake Malawi (FRYER and ILES, 1972) where the feeding grounds of a group of zooplanktivorous *Haplochromis* spp., the 'Utaka', were always located in the vicinity of submerged reefs. Utaka shoals were only found in cases where the reef was situated in the path of a current. It was demonstrated that the fish subsisted on planktonic food carried by currents and concentrated by the passage of water over the reef.

The relationship between pelagic fish and zooplankton in the Southern Sector of Lake Turkana is anomalous. Rates of primary productivity in the southern basin were low compared with more northerly areas of the lake, and pelagic fish were scarce (Table 12.18). Concentrations of zooplankton, however, were similar to those recorded in the Central area of the lake (Table 12.18). It seems possible that although standing stock of zooplankton was relatively high, production rates were much lower than in the Central Sector, with the result that any tendency for pelagic fish to increase led to a reduction in zooplankton densities to unexploitable levels. It is also noteworthy that due to photoenvironmental requirements the pelagic *Alestes* occurred at depths of between 30 and 40 metres during the day in the clear waters of the south, compared with 10-20 metres in the Central Sector. *Tropodiaptomus banforanus*, the principal zooplankter, was situated chiefly in the superficial layers above 30 metres, and feeding in *Alestes* living in the south would be restricted chiefly to the night when the fish migrated towards the surface.

Estimates of total zooplankton production are not available for Lake Turkana, but a value of between 11.7 and 25.9 tonnes/km /year has been calculated for the dominant species, *T. banforanus*. A mean standing stock of 3.7 tonnes/km has been estimated for smaller species of pelagic zooplanktivorous fish. This value does not take into account species such as *Alestes ferox* and *Synodontis schall* in which zooplankton supplements a much wider food regime. Until more information becomes available, it is difficult to draw conclusions on the relationship between these estimates. The present studies, however, indicate that predation pressure by zooplanktivorous fish in the open lake was not sufficiently great to cause radical alterations in the size structure of plankton populations.

SUMMARY

The food of 11 species of smaller fish in which zooplankton features prominently in the diet are analysed. The feeding habits are examined in relation to habitat, time of day and predator size.

The trophodynamic inter-relationships of the zooplanktivorous species are discussed and ways in which food partitioning is achieved both by interspecific and intraspecific differences in feeding behaviour are identified. Scale-eating, observed in several species of fish, is considered to be a sign of food shortage. Population densities of pelagic fish and zooplankton are compared for different sectors of the lake. The concentration of fish which form the midwater scattering layer near the west shore of the Central and Northern Sectors is considered to be the result of the constant replinshment of food resources in this area of the lake by wind-generated surface currents. Relatively high densities of zooplankton in the southern basin are believed to be the result of low rates of predation in the absence of large concentrations of pelagic fish.

REFERENCES

CARMOUZE, J P, DEJOUX, C, DURAND, J R, GRAS, R, ILTIS, A, LAUZANNE, J, LEVEQUE, C, LOUBENS, G and SAINT-JEAN, L (1972). Grandes zones ecologiques du Lac Tchad. Cah. ORSTOM ser. Hydrobiol. 6 : 103-169

CORBET, P S (1961). The food of non-cichlid fishes in the Lake Victoria basin, with remarks on their evolution and adaption to lacustrine conditions. Proc. zool. Soc. Lond. 136 : 1-101.

COULTER, G W (1970). Population changes within a group of fish species in Lake Tanganyika following their exploitation. J. Fish. Biol. 2 : 329-353

FRYER, G and ILES, T D (1972). The cichlid fishes of the great lakes of Africa, their biology and evolution. London, Oliver and Boyd. 641 pp.

HYNES, H B N (1950). The food of freshwater sticklebacks (Gasterosteu aculeatus and Pygosteus pungitius) with a review of the methods used in the studies of the food of fishes. J. Anim. Biol. Ecol. 19 : 36-58.

ROBINSON, A H and ROBINSON, P K (1969). A comparative study of the food habits of Micralestes acutidens and Alestes dageti (Pisces: Characidae) from the northern basin of Lake Chad. Bull. Inst. fr. Afr. noire 31 : 951-964.

YURETICH, R F (1976). Sedimentology, geochemistry and geological significance of modern sediments in Lake Rudolf (Lake Turkana) Eastern Rift Valley, Kenya. PhD thesis, University of Princeton, New Jersey.

TABLE 12.1

Diel study of the food of *Alestes nurse* of 29-60mm F.L. caught during a 24 hour cycle on 6th-7th March 1975 in the Longech area on the east shore of Ferguson's Gulf. Most material was obtained from Lodge Bay, situated at the mouth of the gulf, but after dark *A. nurse* was rare or absent from the sampling site and at 21.45 hrs additional material was obtained from Met Bay approximately 1.5km south. The number of points awarded to each food item has been expressed as a percentage of the total possible score (10,000 per stomach) and the number of points expressed as a percentage of the total actual score is shown in brackets.

Time (hrs E.A.T.) Site	13.00 Lodge Bay	17.45 Lodge Bay	21.00 Lodge Bay	21.45 Met Bay	03.15 Met Bay Lodge Bay	06.15 Lodge Bay	10.15 Lodge Bay
Food items					No *Alestes nurse* caught		
Crustacea :-							
Thermocyclops hyalinus	-	+ (+)	-	-		-	-
Mesocyclops leuckarti	5.4 (7)	3.7 (5)	3.2 (4)	5.3 (9)		6.8 (11)	8.4 (9)
Tropodiaptomus banforanus	64.3 (78)	63.7 (82)	1.6 (2)	-		-	89.7 (91)
Diaphanosoma excisum	2.1 (3)	0.2 (+)	-	+ (+)		+ (+)	0.2 (+)
Ostracods	0.1 (+)	3.2 (+)	1.6 (2)	+ (+)		-	-
Insects :-							
Corixids	10.6 (13)	6.5 (8)	16.0 (20)	1.9 (3)		52.9 (82)	0.4 (+)
Chironomid pupae	-	-	-	50.8 (87)		4.4 (7)	-
Terrestrial coleoptera	-	-	32.0 (40)	-		-	-
All insects	10.6 (13)	6.5 (8)	48.0 (60)	52.7 (90)		57.3 (91)	0.4 (+)
Fish :-							
Unidentified fish	-	-	25.6 (32)	-		-	-
Amorphous remains	-	-	-	0.6 (1)		-	-
% fullness	82.6	77.5	80.0	58.7		64.3	98.7
Number of stomachs	10	10	1	8		10	10
Size range (mm F.L.)	38-51	29-56	60	32-47		35-54	42-54

TABLE 12.2

Diel study of the food of Alestes minutus of 25-35mm F.L. caught by frame trawl 3km east of Longech Spit during 9th-10th April 1974 at a depth of 27m. The number of points awarded to each food item has been expressed as a percentage of the total possible score (10,000 points per stomach) and the number of points expressed as a percentage of the total actual score is shown in brackets.

Station No	179/5	179/10	179/16	179/22	179/25	179/33
Time (hrs E.A.T.)	14/17	17.45	22.50	01.48	07.05	11.48
Food items						
Crustacea :-						
Mesocyclops leuckarti	1.4 (12)	2.0 (13)	1.5 (11)	0.5 (3)	0.2 (2)	-
Tropodiaptomus banforanus	5.0 (43)	9.0 (57)	7.6 (58)	15.2 (91)	9.2 (94)	4.2 (48)
Diaphanosoma excisum	3.7 (32)	3.5 (22)	0.4 (3)	0.8 (4)	0.1 (1)	2.7 (31)
Moina dubia	1.3 (11)	0.2 (2)	-	-	-	-
Ceriodaphnia rigaudi	0.2 (2)	0.1 (1)	-	-	-	0.1 (1)
Hyalodaphnia barbata	-	0.9 (6)	0.4 (3)	0.2 (1)	0.2 (2)	0.1 (1)
All cladocerans	5.2 (45)	4.5 (31)	0.8 (6)	1.0 (5)	0.3 (3)	2.9 (32)
Unidentified prawns	-	-	3.3 (25)	-	-	-
Insects :-						
Chrisonomid pupae	-	-	-	-	-	1.6 (18)
% fullness	11.6	15.6	13.2	16.7	9.8	8.7
Number of stomachs	10	10	10	10	10	10

TABLE 12.3

Analysis of the food of *Alestes minutus* from various localities in Lake Turkana. The number of points awarded to each food item is expressed as a percentage of the total possible score (10,000 points per fish) and the same number expressed as a percentage of the total observed score is shown in brackets.

Locality	Longech	Koobi Fora	Lowarangak	Ilaret	Ilaret	Ilaret	Longech
Lake depth (m)	27	25	30	8	7	8	30
Station number	179	281/14	206/14	274/5	274/6	274/7	259/9
Date	9-10/4/74	3/9/75	20/7/74	7/8/75	7/8/75	7/8/75	9/7/75
Time (hrs E.A.T.)	24 hr series	10.12	13/40	11.56	12.25	13.00	15.30
Food items							
Microcystis	-	-	-	-	-	+ (+)	-
Crustacea :-							
Mesocyclops leuckarti	0.9 (7)	10.5 (14)	0.2 (4)	0.2 (2)	0.1 (1)	-	-
Thermocyclops hyalinus	-	0.9 (1)	0.1 (2)	-	-	-	-
Tropodiaptomus banforanus	8.3 (67)	61.3 (83)	0.4 (11)	8.4 (92)	2.8 (34)	5.9 (36)	-
Diaphanosoma excisum	1.9 (15)	0.3 (+)	-	0.1 (1)	0.8 (10)	3.5 (22)	-
Moina dubia	0.2 (2)	0.6 (1)	-	0.3 (4)	-	0.4 (2)	-
Ceriodaphnia rigaudi	+	-	-	0.2 (2)	-	-	-
Hyalodaphnia barbata	0.3 (2)	0.1 (+)	-	-	-	-	-
All cladocera	2.4 (19)	1.0 (1)	-	0.6 (7)	0.8 (10)	3.9 (24)	-
Unidentified prawns	0.5 (4)	-	-	-	-	0.1 (1)	
Caridina nilotica	-	1.3 (2)					
Insects :-							
Chironomid pupae	0.3 (2)	-	-	-	-	-	-
Fish :-							
Unidentified fish	-	-	-	-	-	0.2 (1)	-
Fish scales	-	-	3.5 (84)	-	4.4 (55)	2.3 (14)	-
Amorphous remains	-	-	-	-	-	3.2 (19)	
% fullness	12.4	75.0	4.2	9.1	8.2	16.4	0
Number of stomachs	60	23	4	10	10	10	10
Size range (mm F.L.)	24.35	12-31	27-30	24.31	24.31	27.32	23-28

TABLE 12.4

Diel study of the food of *Alestes ferox* of 28-65mm F.L. caught during a 24 hrs period on 9-10/4/74 by frame trawl 3 km east of Longech Spit at a depth of 27m. The number of points awarded to each food item has been expressed as a percentage of the total possible score (10,000 per stomach) and the number of points expressed as a percentage of the total actual score is shown in brackets.

Time	Afternoon	Dusk	Night	Dawn	Mid-morning
Food items					
Microcystis	0.5 (3)	0.2 (1)	0.2 (1)	+	+
Crustacea :-					
Thermocyclops hyalinus	-	+	+	-	-
Mesocyclops leuckarti	0.4 (3)	1.1 (4)	2.2 (5)	0.7 (1)	0.5 (3)
Tropodiaptomus banforanus	2.5 (15)	6.9 (28)	7.5 (16)	29.8 (62)	4.7 (33)
Diaphanosoma excisum	4.1 (24)	1.9 (7)	0.9 (2)	0.7 (1)	0.5 (3)
Moina dubia	0.4 (2)	0.2 (1)	+	-	0.1 (1)
Ceriodaphnia rigaudi	-	+	+	-	-
Hyalodaphnia barbata	1.5 (9)	0.8 (3)	2.4 (5)	0.5 (1)	0.3 (2)
All cladocerans	6.0 (35)	2.9 (11)	3.3 (7)	1.2 (2)	0.9 (6)
Ostracods	-	-	-	+	0.5 (3)
Argulids	1.2 (7)	-	-	-	-
Macrobrachium niloticum	1.4 (8)	3.3 (13)	2.8 (6)	-	-
Caridina nilotica	-	3.3 (13)	5.5 (12)	-	-
Unidentified prawns	0.6 (4)	0.4 (3)	0.6 (1)	0.3 (1)	-
All prawns	2.0 (12)	7.0 (28)	8.9 (19)	0.3 (1)	-
Insects :-					
Corixids	-	-	0.2 (+)	1.0 (2)	-
Chironomid pupae	-	-	0.1 (+)	-	-
Chironomid adults	-	-	3.2 (7)	13.1 (27)	5.0 (36)
Unidentified insects	0.3 (2)	-	-	-	-
All insects	0.3 (2)	-	3.7 (7)	14.1 (29)	5.0 (36)
Fish :-					
Alestes minutus	-	2.0 (8)	17.0 (37)	1.5 (3)	1.0 (7)
A. ferox	-	2.0 (8)	1.4 (3)	-	-
Fish scales	-	0.3 (1)	+	-	0.6 (4)
Eggs *Lates niloticus*	-	-	-	0.4 (1)	-
Unidentified fish	2.9 (17)	-	2.2 (5)	-	-
All fish	2.9 (17)	4.3 (17)	20.6 (45)	1.9 (4)	1.6 (11)
Amorphous remains	1.2 (7)	2.4 (10)	-	-	0.4 (3)
% fullness	17.2	25.0	46.6	48.3	14.0
Number of stomachs	37	45	45	32	31
Size range (mm F.L.)	35.62	28-65	31-63	35.64	34-65

TABLE 12.5

Analysis of the food of *Alestes ferox* from various localities in Lake Turkana. The number of points awarded to each food item is expressed as a percentage of the total possible score (10,000 points per fish) and the same number expressed as a percentage of the actual score is shown in brackets.

Locality	Longech	Longech	Namadak	Longech	Longech
Lake depth (m)	27	30	16	30	33
Station number	179	109/1	121/2	282/1	282/2
Date	9-10/4/74	20/7/73	24/8/73	23/9/75	23/9/75
Time (hrs E.A.T.)	24hr series	12.30	14.13	13.53	16.14
Food items					
Microcystis	0.2 (1)	-	+ (+)	+ (+)	+ (+)
Crustacea :-					
Thermocyclops hyalinus	0.1 (+)	-	-	0.2 (3)	-
Mesocyclops leuckarti	1.0 (3)	-	0.7 (9)	-	-
Tropodiaptomus banforanus	9.7 (32)	-	1.6 (21)	-	-
Diaphanosoma excisum	1.8 (6)	-	-	0.1 (1)	+ (+)
Moina dubia	0.2 (1)	-	+ (+)	-	-
Ceriodaphnia rigaudi	+ (+)	-	-	-	-
Hyalodaphnia barbata	+ (4)	-	0.1 (1)	-	+ (+)
All cladocerans	2.0 (11)	-	0.1 (1)	0.1 (1)	+ (+)
Ostracods	0.2 (1)	-	-	-	-
Argulids	0.2 (1)	-	-	-	-
Macrobrachium niloticum	1.7 (6)	3.7 (15)	-	1.6 (22)	2.3 (39)
Caridina nilotica	2.1 (7)	-	-	-	-
Unidentified prawns	0.4 (1)	0.2 (1)	-	-	-
All prawns	4.6 (18)	3.9 (16)	-	1.6 (22)	2.3 (39)
Insects :-					
Povilla	-	-	0.1 (2)	-	-
Corixids	0.2 (1)	-	-	-	-
Chironomid pupae	+ (+)	-	-	-	-
Chironomid adults	3.8 (12)	-	-	-	-
Unidentified insects	+ (+)	-	0.2 (2)	1.5 (21)	-
All insects	4.0 (13)	-	0.3 (4)	1.5 (21)	-
Fish :-					
Alestes minutus	4.8 (16)	-	1.6 (22)	2.4 (33)	0.3 (4)
A. ferox	0.8 (3)	-	-	-	-
Engraulicypris stellae	-	19.2 (81)	-	-	-
Haplochromis macconneli	-	+ (+)	-	-	-
Lates spp. post larvae	-	-	+	-	-
Fish scales	0.2 (1)	-	-	-	-
Eggs *Lates niloticus*	+ (+)	-	-	-	-
Unidentified fish	1.1 (4)	0.6 (2)	3.0 (40)	1.5 (21)	2.4 (43)
All fish	6.9 (24)	19.8 (83)	4.6 (62)	3.9 (54)	2.7 (47)
Amorphorus remains	0.9 (3)	+ (+)	+ (+)	+ (+)	-
% fullness	30.7	23.8	7.5	7.3	5.7
Number of stomachs	190	29	34	10	10
Size range (mm F.L.)	28-65	60-120	48-109	53-91	55-103

TABLE 12.6

Analysis of the food of *Micralestes acutidens* from various localities in Lake Turkana. The number of points awarded to each food item is expressed as a percentage of the total possible score (10,000 points per fish) and the same number expressed as a percentage of the actual score is shown in brackets.

Locality	Longech shore	Longech shore	Longech shore	Todenyang shore	Ilaret	Ilaret	Ilaret	Todenyang
Lake depth (m)	-	-	-	-	8	7	8	
Station number	-	-	-	-	274/5	274/6	274/7	
Date	9/12/72	9/12/72	6/3/75	16/11/72	7/8/75	7/8/75		
Time (hours E.A.T.)	daytime	daytime	21.30	daytime	11.56	12.25	13.00	
Food items								
Algae :-								
Microcystis	3.9 (5)	3.2 (3)	-	67.2 (71)	94.2 (97)	21.6 (95)	81.0 (93)	1.9 (19)
Oscillatoria	-	-	-	0.2 (+)	-	-	-	-
Botryococcus	-	-	-	0.4 (+)	-	-	-	-
Surirella	-	-	-	-	-	-	-	0.4 (4)
All algae	3.9 (5)	3.2 (3)	-	67.6 (72)	94.2 (97)	21.6 (95)	81.0 (93)	2.3 (23)
Macrophyte fragments	0.2 (+)	-	-	-	-	-	-	-
Crustacea :-								
Thermocyclops hyalinus	*	*	-	*	0.1 (+)	-	-	-
Mesocyclops leuckarti	*	*	1.3 (3)	*	1.5 (1)	+ (+)	1.8 (2)	3.2 (33)
All cyclopoid copepods	4.1 (5)	13.1 (14)	1.3 (3)	7.0 (7)	1.6 (1)	+ (+)	1.8 (2)	3.2 (33)
Tropodiaptomus banforanus	44.7 (59)	3.5 (4)	3.2 (8)	1.5 (2)	1.4 (1)	0.2 (1)	2.6 (3)	3.0 (30)
Diaphanosoma excisum	*	*	-	*	0.1 (+)	0.1 (+)	1.1 (1)	0.1 (1)
Moina dubia	*	*	-	*	0.1 (+)	+ (+)	-	-
All cladocera	7.6 (10)	36.4 (38)	-	17.1 (18)	0.2 (+)	0.1 (+)	1.1 (1)	0.1 (1)
Ostracods	3.7 (5)	32.6 (34)	0.8 (2)	0.4 (+)	-	-	-	-
Argulids	-	-	-	-	-	+ (+)	-	-
Insects :-								
Corixids	5.1 (7)	6.6 (7)	-	0.2 (+)	-	-	-	-
Chironomid larvae	-	-	-	0.7 (1)	-	-	-	0.7 (7)
Chironomid pupae	-	-	34.7 (87)	-	-	-	-	-
Coleopteran larvae	1.5 (2)	-	-	-	-	-	-	-
Unidentified insects	3.1 (4)	-	-	-	-	-	-	-
All insects	8.7 (13)	6.6 (7)	34.7 (87)	0.9 (1)	-	-	-	0.7 (7)
Hydracarina	1.8 (2)	0.4 (+)	-	-	+ (+)	-	+ (+)	+ (+)
Fish :-								
Fish scales	-	-	-	-	-	0.7 (3)	0.7 (1)	0.4 (4)
Fish eggs	-	-	-	-	-	+ (+)	-	-
All fish	-	-	-	-	-	0.7 (3)	0.7 (1)	0.4 (4)
Amorphous remains	-	-	-	-	-	0.1 (+)	0.4 (+)	-
% fullness	75.8	95.8	40.0	94.8	97.4	22.7	87.5	9.9
Number of stomachs	10	10	2	21	16	10	10	5
Size range (mm F.L.)	35-39	18-22	32-38	21-33	29-35	31-38	31-35	28-36

TABLE 12.7

Analysis of the food of *Barbus turkanae* from various localities in Lake Turkana. The number of points awarded to each food item has been expressed as a percentage of the total possible score for each sample (10,000 points per fish). The same number expressed as a percentage of the actual score is shown in brackets.

Locality	Allia	Namadak	Jarigole	Central Sector	Central Island	Central Sector
Lake depth (m)	42	30	34	70	76	60
Station number	25/6	93/7	119/2	127/1	131/1	206/22
Date	24/8/72	14/5/73	20/8/73	5/9/73	21/9/73	21/7/74
Time (hrs E.A.T.)	14.08	15.25	13.48	14.50	13.13	17.31
Food items						
Crustacea :-						
Mesocyclops leuckarti	-	0.4 (1)	-	1.0 (2)	0.3 (1)	0.1 (3)
Moina dubia	-	0.8 (3)	-	-	-	-
Ostracods	-	23.2 (83)	0.9 (2)	23.8 (45)	20.5 (72)	0.4 (10)
Caridina nilotica	26.3 (51)	-	-	-	-	-
Unidentified prawns	7.5 (15)	-	-	10.0 (19)	-	-
Insects :-						
Chironomid larvae	-	3.6 (13)	-	18.5 (35)	-	3.8 (87)
Naucorids	-	-	47.7 (93)	-	-	-
Unidentified insects	12.5 (24)	-	-	-	-	-
Molluscs :-						
Cleopatra pirothi	-	-	-	-	4.3 (15)	-
Unidentified mollusc remains	5.0 (10)	-	-	-	-	-
Amorphous remains	-	-	2.8 (6)	-	3.4 (12)	-
% fullness	51.2	28.0	51.4	53.2	28.6	4.4
Number of stomachs	2	5	7	6	7	5
Size range (mm F.L.)	46-49	31-42	27-41	30-37	29-38	39-46

TABLE 12.8

Diel study of the food of *Barilius niloticus* caught during a 24 hour cycle on 15-16/7/75 on the shore at Crater Bay, Central Island. The number of points awarded to each food item has been expressed as a percentage of the total possible score (10,000 points per stomach). The same number expressed as a percentage of the actual score is shown in brackets. Data have been analysed separately for two size groups of fish.

	(a) Smaller fish 10-22mm F.L.					
Time (hrs E.A.T.)	12.00	15.40	18.40	24.00	06.30	10.00
Food items						
Algae :-						
Microcystis	-	-	-	-	+ (+)	-
Phormidium	0.5 (1)	-	-	-	-	-
Diatoms (sessile)	7.6 (17)	2.0 (4)	+ (+)	-	0.1 (4)	-
Crustacea :-						
Mesocyclops leuckarti	1.5 (3)	10.2 (18)	21.5 (44)	-	0.4 (13)	-
Tropodiaptomus banforanus	-	7.9 (14)	1.1 (2)	-	-	-
Harpacticoids	6.0 (13)	-	-	-	-	-
Copepod nauplii	4.5 (10)	36.3 (63)	25.5 (52)	-	0.3 (9)	-
Hyalodaphnia barbata	-	-	-	-	0.8 (24)	-
Ostracods	22.8 (51)	0.3 (1)	-	-	-	-
Macrobrachium niloticum	-	-	0.3 (1)	-	-	-
Caridina nilotica	-	-	-	-	-	-
All prawns	-	-	0.3 (1)	-	-	-
Insects :-						
Caeniid nymphs	-	-	-	-	1.0 (30)	-
Chloeonid nymphs	-	-	-	-	-	-
Plecopteran nymphs	-	-	-	-	-	-
Terrestrial Hemiptera-Heteroptera	-	-	-	-	-	-
Coleopteran larvae	-	-	-	-	-	-
Lepidoptera	-	-	-	-	-	-
Hymenoptera	-	-	-	-	-	-
Chironomid larvae	1.6 (4)	0.4 (1)	0.3 (1)	-	0.6 (17)	-
Chironomid pupae	-	-	-	-	-	-
Chironomid adults	-	-	-	-	-	5.0 (100)
Unidentified insects	0.5 (1)	-	-	-	-	-
All insects	2.1 (5)	0.4 (1)	0.3 (1)	-	1.6 (47)	5.0 (100
Fish :-						
Unidentified fish	-	-	-	-	-	-
Amorphous remains	-	-	-	-	0.1 (3)	-
% fullness	45.0	57.3	48.7	0	3.3	50.0
Number of stomachs	10	10	10	5	10	1
Size range (mm F.L.)	16-19	10-17	13-16	13-22	14-18	

TABLE 12.8 Sheet 2 (contd.)

	(b) Larger fish 34-52mm F.L.					
Time (hrs E.A.T.)	12.00	15.40	18.40	24.00	06.30	10.00
Food items						
Algae :-						
Microcystis	-	-	-	0.2 (+)	-	-
Phormidium	12.3 (24)	-	+ (+)	-	6.4 (11)	3.9 (20)
Diatoms (sessile)	17.2 (33)	-	+ (+)	-	0.1 (+)	0.3 (2)
Crustacea :-						
Mesocyclops leuckarti	0.1 (+)	23.0 (80)	9.1 (48)	10.8 (17)	-	-
Tropodiaptomus banforanus	-	-	-	+ (+)	-	-
Harpacticoids	-	-	-	-	-	-
Copepod nauplii	-	-	-	-	-	-
Hyalodaphnia barbata	-	-	-	-	-	-
Ostracods	8.9 (17)	3.9 (14)	0.8 (4)	+ (+)	-	-
Macrobrachium niloticum	-	-	0.6 (2)	-	-	-
Caridina nilotica	-	-	-	13.7 (22)	0.5 (1)	-
All prawns	-	-	0.6 (2)	13.7 (22)	0.5 (1)	-
Insects :-						
Caenid nymphs	-	-	-	-	6.8 (12)	-
Chloeonid nymphs	-	-	-	-	33.3 (57)	4.2 (22)
Plecopteran nymphs	-	-	4.5 (24)	5.3 (9)	-	-
Terrestrial Hemiptera-Heteroptera	9.1 (17)	-	-	-	-	-
Coleopteran larvae	0.9 (2)	-	-	-	-	-
Lepideptora	0.5 (1)	-	-	-	-	-
Hymenoptera	-	1.0 (3)	-	0.3 (+)	-	-
Chironomid larvae	1.3 (2)	+ (+)	1.9 (10)	0.8 (1)	1.6 (3)	7.9 (41)
Chironomid pupae	0.6 (1)	-	1.4 (7)	4.6 (7)	-	1.6 (9)
Chironomid adults	0.3 (1)	-	0.6 (3)	25.8 (42)	8.2 (14)	1.0 (5)
Unidentified insects	-	-	+ (+)	-	1.6 (3)	-
All insects	12.7 (24)	1.0 (3)	8.4 (44)	36.8 (59)	51.5 (89)	14.7 (77)
Fish :-						
Unidentified fish	-	-	-	0.3 (1)	-	0.2 (1)
Amorphous remains	0.8 (2)	-	-	-	-	-
% fullness	52.0	28.6	18.4	62.0	58.4	19.1
Number of stomachs	10	10	8	10	10	10
Size range (mm F.L.)	37-48	35-44	35-48	41-49	37-52	34-40

TABLE 12.9

Analysis of the food of *Barilius niloticus* from various localities in Lake Turkana. The number of points awarded to each food item is expressed as a percentage of the total possible score (10,000 points per fish) and the same number expressed as a percentage of the actual score is shown in brackets.

Locality	Longech shore	Central Island shore	Central Island shore	Kakoi shore	Kakoi shore	Ballo shore	South Island shore
Station number	-	H3	H3	221/AA	221/AA	D6	-
Date	7/3/75	15-16/7/75	15-16/7/75	24/10/74	24/10/75	22/1/75	27/11/74
Time (hrs E.A.T.)	06.30	diel study	diel study	daytime	daytime	daytime	daytime
Food items							
Algae :-							
Microcystis	-	+ (+)	-	-	-	-	-
Phormidium	-	0.1 (+)	3.9 (10)	-	-	-	-
Diatoms (sessile)	-	2.1 (6)	3.0 (8)	0.1 (1)	-	-	-
Diatoms (planktonic)	-	-	-	-	-	5.8 (17)	0.3 (+)
Crustacea :-							
Thermocyclops hyalinus	-	-	-	-	-	0.1 (2)	-
Mesocyclops leuckarti	0.6 (4)	7.3 (22)	7.1 (18)	-	1.9 (3)	3.3 (10)	28.4 (37)
Tropodiaptomus banforanus	-	1.9 (6)	+ (+)	-	-	-	-
Harpacticoids	-	1.3 (4)	-	-	-	-	-
Copepod nauplii	-	14.5 (43)	-	-	-	-	-
Diaphanosoma excisum	-	-	-	38.9 (86)	52.9 (83)	16.9 (49)	44.3 (57)
Moina dubia	-	-	-	6.0 (13)	9.1 (14)	-	-
Ceriodaphnia rigaudi	-	-	-	-	+ (+)	-	-
Hyalodaphnia barbata	-	0.2 (1)	-	-	-	-	-
Unidentified cladocera	-	-	-	-	-	1.5 (4)	-
All cladocera	-	0.2 (1)	-	44.9 (99)	62.0 (97)	18.4 (53)	44.3 (57)
Ostracods	6.0 (46)	5.0 (15)	2.3 (6)	-	-	-	-
Macrobrachium niloticum	-	+ (+)	0.1 (+)	-	-	-	-
Caridina nilotica	-	-	2.4 (6)	-	-	-	-
All prawns	-	+ (+)	2.5 (6)	-	-	-	-
Insects :-							
Caenid nymphs	-	0.1 (+)	1.2 (3)	-	-	-	-
Chloeonid nymphs	-	-	6.4 (16)	-	-	-	-
Plecopteran nymphs	-	-	1.5 (4)	-	-	-	-
Terrestrial Hemiptera-Heteroptera	-	-	1.5 (4)	-	-	-	-
Coleopteran larvae	-	-	0.2 (1)	-	-	-	-
Trichopteran larvae	-	-	-	-	-	-	0.8 (1)
Lepidoptera	-	-	0.1 (+)	-	-	-	-
Hymenoptera	-	-	0.2 (1)	-	-	-	-
Chironomid larvae	3.9 (30)	0.6 (2)	2.3 (6)	-	-	6.1 (18)	3.9 (5)
Chironomid pupae	2.7 (20)	-	1.4 (4)	-	-	-	-
Chironomid adults	-	0.1 (+)	6.2 (15)	-	-	-	-
Unidentified insects	-	0.1 (+)	-	-	-	-	-
All insects	6.6 (50)	0.9 (2)	21.0 (52)	-	-	6.1 (18)	4.7 (6)
Fish :-							
Unidentified fish	-	-	0.1 (+)	-	-	-	-
Amorphous remains	-	+ (+)	0.1 (+)	-	-	-	-
% fullness	13.2	33.5	40.5	45.0	64.0	34.2	77.8
Number of stomachs	12	46	58	10	10	10	10
Size range	22-34	10-22	34-52	10-17	25-31	12-21	29-46

TABLE 12.10

Diel study of the food of *Engraulicypris stellae* caught during a 24 hour cycle at Met Bay, Longech, on the east shore of Ferguson's Gulf during 6-7/3/75. The number of points awarded to each food item has been expressed as a percentage of the total possible score (10,000 per stomach). The same number expressed as a percentage of the actual score is shown in brackets. Additional data for fish collected 1.5km north at Lodge Bay is provided for the final sampling period.

Locality	Met Bay						Lodge Bay
Time (hrs E.A.T.)	12.30	17.15	21.30	03.15	06.30	10.30	10.15
Food items							
Crustacea :-							
Thermocyclops hyalinus	-	-	-	-	-	-	+ (+)
Mesocyclops leuckarti	80.0 (100)	15.6 (42)	0.5 (1)	-	0.1 (+)	21.7 (100)	7.2 (9)
Tropodiaptomus banforanus	-	-	-	-	-	-	63.6 (83)
Diaphanosoma excisum	-	-	-	-	-	+ (+)	0.6 (1)
Ceriodaphnia rigaudi	-	-	-	-	-	-	0.2 (+)
Hyalodaphnia barbata	-	+ (+)	-	-	0.5 (1)	+ (+)	4.7 (6)
All cladocera	-	+ (+)	-	-	0.5 (1)	+ (+)	5.5 (7)
Ostracods	-	0.9 (2)	-	-	+ (+)	-	-
Insects :-							
Corixids	-	-	7.2 (15)	-	4.0 (7)	-	-
Chironomid larvae	-	8.7 (23)	6.0 (12)	5.3 (17)	-	-	-
Chironomid pupae	-	9.8 (26)	35.2 (72)	26.7 (83)	53.4 (91)	-	-
Amorphous remains	-	2.2 (6)	-	-	-	-	-
% fullness	80.0	37.2	49.0	32.0	58.5	21.7	76.5
Number of stomachs	10	10	10	10	10	10	10
Size range (mm F.L.)	20-25	22-52	20-25	21-25	22-26	21-24	22-27

TABLE 12.11

Changes in the food of *Engraulicypris stellae* over a period of 13 hours in the open lake at station H1, 2km north of Central Island during 19-20/2/73. The number of points awarded to each food item has been expressed as a percentage of the total possible score for each sampling period. The same number expressed as a percentage of the actual score is shown in brackets.

Time (hrs E.A.T.)	19.15	22.15	04.35	08.15
Food items				
Microcystis	-	-	-	0.2 (2)
Crustacea :-				
Mesocyclops leuckarti	-	-	-	0.5 (5)
Tropodiaptomus hyalinus	6.5 (88)	0.1 (50)	-	0.6 (6)
Diaphanosoma excisum	-	-	-	6.2 (60)
Hyalodaphnia barbata	-	-	0.2 (50)	-
All cladocera	-	-	0.2 (50)	6.2 (60)
Caridina nilotica	-	-	-	2.2 (22)
Amorphous remains	0.9 (12)	0.1 (50)	0.2 (50)	0.5 (5)
% fullness	7.4	0.2	0.4	10.2
Number of stomachs	10	.10	10	10
Size range (mm F.L.)	24-27	25-27	22-26	24-27

TABLE 12.12

Analysis of the food of Engraulicypris stellae from various localities in Lake Turkana. The number of points awarded to each food item has been expressed as a percentage of the total possible score for each sampling period (10,000 points per stomach). The same number expressed as a percentage of the actual score is shown in brackets.

Locality	Longech Met Bay shore	Longech Met Bay shore	Longech Lodge Bay shore	Longech Lodge Bay shore	Central Island shore	Central Island shore	Central Island	Longech-Allia	Longech Allia	Longech-Allia	Moite	Moite
Lake depth (m)	-	-	-	-	-	-	80	80	84	40	47	47
Station number	-	-	-	-	H3	H3	78	242/1	242/4	242/6	207/33	207/33
Date	6-7/3/75	6/3/75	7/3/75	9/12/72	15/7/75	15/7/75	19-20/2/73	26/2/75	27/2/75	28/2/75	28/7/74	28/7/74
Time (hrs E.A.T.)	diel series	12.30	10.15	daytime	18.40	24.00	19.00-08.15	13.20	14.07	13.20	11.29	11.29
Food items												
Algae :-												
Microcystis	-	-	-	-	-	-	+ (+)	-	-	-	-	0.1 (+)
Paranema	-	-	-	-	-	-	-	-	-	-	-	+ (+)
Surirella	-	-	-	-	-	-	-	-	-	-	5.8 (12)	0.3 (+)
Gomphonema	-	-	-	-	-	-	-	-	-	-	-	+ (+)
Horinidium	-	-	-	-	-	-	-	-	-	-	-	+ (+)
Thuricola	-	-	-	-	-	-	-	-	-	-	-	+ (+)
Gyratrix eggs	-	-	-	-	-	-	-	-	-	-	-	+ (+)
Crustacea :-												
Thermocyclops hyalinus	-	-	0.1 (+)	*	-	-	-	-	-	-	1.8 (2)	6.2 (7)
Mesocyclops leuckarti	23.8 (42)	53.0 (100)	7.3 (9)	*	37.0 (83)	13.7 (40)	0.1 (3)	0.2 (18)	-	0.8 (17)	28.0 (56)	48.2 (55)
All cyclopoid copepods	23.6 (42)	53.0 (100)	7.4 (9)	0.7 (3)	37.0 (83)	13.7 (40)	0.1 (3)	0.2 (18)	-	0.6 (17)	29.8 (58)	54.4 (82)
Tropodiaptomus banforanus	-	-	63.6 (83)	4.4 (17)	1.7 (4)	-	1.8 (40)	+ (5)	-	0.5 (14)	9.2 (18)	26.0 (30)
Diaphanosoma excisum	- (+)	-	0.6 (1)	*	-	-	1.5 (34)	-	-	-	3.2 (6)	4.6 (5)
Moina dubia	-	-	-	*	-	-	-	-	-	0.3 (8)	3.0 (6)	1.8 (2)
Ceriodaphnia rigaudi	-	-	0.2 (+)	*	-	-	-	+ (2)	+ (2)	0.1 (3)	-	+ (+)
Hyalodaphnia barbata	0.1 (+)	-	4.7 (6)	*	-	-	+ (+)	+ (1)	-	-	-	+ (+)
All cladocera	0.1 (+)	-	5.5 (7)	0.4 (2)	-	-	1.5 (34)	+ (3)	-	0.4 (11)	-	-
Ostracods	0.2 (+)	-	-	16.8 (63)	-	-	-	-	-	-	-	-
Caridina nilotica	-	-	-	-	-	-	0.6 (12)	-	-	-	-	0.3 (+)
Insects :-												
Corixids	2.2 (4)	-	-	1.1 (4)	-	-	-	-	-	-	-	-
Terrestrial Hemiptera-Heteroptera	-	-	-	1.8 (7)	-	-	-	-	-	-	-	-
Chironomid larvae	4.0 (7)	-	-	-	-	3.1 (9)	-	-	-	-	-	-
Chironomid pupae	25.0 (45)	-	-	-	-	-	-	-	-	-	-	-
Chironomid adults	-	-	-	-	6.1 (14)	17.7 (51)	-	-	-	-	-	-
Unidentified insects	-	-	-	0.4 (2)	-	-	-	-	-	-	-	+ (+)
All insects	31.2 (56)	-	-	3.3 (13)	6.1 (14)	20.8 (60)	-	-	-	0.3 (8)	-	+ (+)
Amorphous remains	0.4 (1)	-	-	-	-	-	0.4 (9)	0.9 (24)	0.5 (98)	1.4 (39)	-	-
% fullness	55.6	53.0	76.5	26.5	44.8	34.5	4.6	1.2	0.5	3.6	50.3	87.6
Number of stomachs	60	10	10	10	10	9	40	39	15	10	3	16
Size range (mm F.L.)	20-26	15-19	22-27	22-27	26-30	22-31	22-27	20-27	24-27	23-29	14-18	20-28

TABLE 12.13

Analysis of the food of *Chelaethiops bibie* from various localities in Lake Turkana. The number of points awarded to each food item is expressed as a percentage of the total possible score (10,000 points per fish) and the same number expressed as a percentage of the actual score is shown in brackets.

Locality	Todenyang shore	Ilaret	Ilaret
Lake depth (m)	-	6	8
Station number	-	274/6	274/7
Date	5/3/73	7/8/75	7/8/75
Time (hrs E.A.T.)	daytime	12.25	13.00
Food items			
Microcystis	-	-	2.0 (14)
Grass seeds	1.8 (3)	-	3.1 (23)
Macrophyte fragments	-	0.1 (2)	-
Crustacea :-			
Mesocyclops leuckarti	+ (+)	-	-
Tropodiaptomus banforanus	3.7 (7)	-	-
Diaphanosoma excisum	-	-	+ (+)
Hyalodaphnia barbata	-	0.3 (5)	-
All cladocera	-	0.3 (5)	+ (+)
Ostracods	0.1 (+)	-	-
Unidentified prawns	-	-	+ (+)
Insects :-			
Corixids	7.8 (15)	0.1 (2)	-
Terrestrial Hemiptera-Heteroptera	-	1.0 (16)	-
Coleoptera larvae	3.0 (6)	0.4 (7)	-
Chironomid larvae	23.4 (45)	-	-
Chironomid pupae	10.0 (19)	-	-
Chironomid adults	-	0.3 (4)	-
Hymenoptera	-	1.5 (24)	-
Unidentified insects	-	-	0.1 (1)
All insects	36.4 (70)	3.3 (53)	0.1 (1)
Hydracarina	-	-	0.1 (1)
Fish :-			
Unidentified fish	-	-	2.5
Fish scales	-	1.7 (28)	1.5 (11)
Amorphous remains	1.9 (4)	0.8 (12)	4.2 (31)
% fullness	51.8	6.1	13.6
Number of stomachs	10	10	10
Size range (mm F.L.)	33-37	30-37	34-40

TABLE 12.14

Analysis of the food of *Aplocheilichthys rudolfianus* from the shore of the northern extremity of Longech Spit. The number of points awarded to each food item has been expressed as a percentage of the total possible score for each sampling period (10,000 points per stomach). The same number expressed as a percentage of the total actual score is shown in brackets.

Food items	
Mesocyclops leuckarti	3.6 (17)
Cyclopoid nauplii	+ (+)
Tropodiaptomus banforanus	17.2 (82)
Diaphanosoma excisum	+ (+)
% fullness	20.9
Number of stomachs	6
Size range (mm T.L.)	21-32

TABLE 12.15

Diel study of the food of juvenile *Lates* spp. of 22-37 mm T.L. caught during a 24 hour cycle at Lodge Bay, Longech, on the east shore of Ferguson's Gulf during 6-7/3/75. The number of points awarded to each food item has been expressed as a percentage of the total possible score for each sampling period (10,000 points per stomach). The same number expressed as a percentage of the actual score is shown in brackets.

Time	13.00	17.45	21.30	03.15	06.15	10.15
Food items						
Crustacea :-						
Mesocyclops leuckarti	12.8 (14)	2.1 (3)	3.0 (12)	-	+ (1)	9.3 (12)
Tropodiaptomus banforanus	32.1 (34)	43.1 (64)	3.4 (14)	-	-	59.0 (77)
Diaphanosoma excisum	9.1 (10)	0.5 (1)	-	-	-	1.6 (2)
Moina dubia	-	-	-	-	-	0.9 (1)
Hyalodaphnia barbata	-	-	-	-	-	0.5 (1)
All cladocera	9.1 (10)	0.5 (1)	-	-	-	3.0 (4)
Ostracods	1.3 (1)	4.0 (6)	4.1 (17)	-	-	0.5 (1)
Caridina nilotica	3.5 (4)	3.5 (5)	1.4 (6)	-	-	-
Insects :-						
Corixids	11.0 (12)	2.8 (4)	1.7 (7)	-	2.9 (25)	0.8 (1)
Chironomid larvae	-	1.0 (1)	-	-	-	-
Fish :-						
Barilius niloticus	9.0 (9)	8.5 (13)	-	-	9.0 (75)	-
Lates niloticus	-	-	9.8 (40)	-	-	-
Unidentified fish	16.2 (17)	2.0 (3)	1.9 (8)	-	-	4.5 (6)
All fish	25.2 (26)	10.5 (16)	11.7 (48)	-	9.0 (75)	4.5 (6)
% fullness	95.0	67.5	24.2	0	12.0	77.1
Number of stomachs	10	10	8	10	10	10
Size range (mm T.L.)	25-35	26-35	24-37	22-36	26-34	23-31

TABLE 12.16

Analysis of the food of *Lates* spp. post larvae and juveniles from various localities in Lake Turkana. The number of points awarded to each food item has been expressed as a percentage of the total possible score for each sample (10,000 points per stomach). The same number expressed as a percentage of the actual score is shown in brackets.

Locality	Longech Lodge Bay shore		Longech Lodge Bay shore		Northern Sector		Northern Sector	
Lake depth (m)	-		-		22		22	
Station number	-		-		281/4A		281/4A	
Date	23/5/74		6-7/3/75		3/9/75		3/9/75	
Time (hrs E.A.T.)	daytime		diel series		13.35		13.35	
Food items								
Crustacea :-								
Afrocyclops gibsoni	4.3	(7)	-		-		-	
Thermocyclops hyalinus	2.0	(3)	-		-		0.4	(1)
Mesocyclops leuckarti	41.3	(62)	4.6	(10)	27.5	(34)	22.3	(38)
Tropodiaptomus banforanus	1.6	(2)	23.6	(50)	39.8	(50)	52.3	(65)
Diaphanosoma excisum	-		1.9	(4)	10.9	(14)	3.6	(5)
Moina dubia	-		0.2	(+)	1.4	(2)	1.0	(1)
Hyalodaphnia barbata	-		0.1	(+)	0.3	(+)	0.2	(+)
All cladocera	-		2.2	(5)	12.6	(16)	4.8	(6)
Ostracods	+	(+)	1.6	(3)	-		-	
Caridina nilotica	-		1.4	(3)	-		-	
Insects :-								
Corixids	-		3.3	(7)	-		-	
Anisops	11.6	(17)	-		-		-	
Chironomid larvae	1.5	(2)	0.2	(+)	-		-	
Fish :-								
Barilius niloticus	-		4.6	(10)	-		-	
Lates niloticus	4.3	(7)	1.3	(3)	-		-	
Unidentified fish	-		4.2	(9)	-		-	
All fish	4.3	(7)	10.1	(22)	-		-	
% fullness	66.6		46.8		80.0		80.0	
Number of stomachs	10		58		11		19	
Size range (mm T.L.)	11-26		22-37		4-8		8-12	

TABLE 12.17

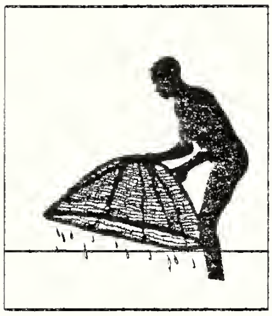
Diel study of the food of *Haplochromis rudolfianus* of 32-49mm T.L. caught during a 24 hour cycle at Lodge Bay, Longech, on the east shore of Ferguson's Gulf during 6-7/3/75. The number of points awarded to each food item has been expressed as a percentage of the total possible score for each sampling period (10,000 points per stomach). The same number expressed as a percentage of the actual score is shown in brackets.

Time (hrs E.A.T.)	13.00	17.45	21.30	03.15	06.15	10.15
Food items	0.5 (2)					
Crustacea :-						
Mesocyclops leuckarti	0.5 (2)	-	-	-	-	-
Tropodiaptomus banforanus	0.6 (2)	-	-	-	-	5.1 (39)
Diaphanosoma excisum	1.6 (5)	-	-	-	-	1.1 (8)
Ostracods	4.7 (14)	-	1.0 (14)	0.8 (15)	4.0 (53)	6.9 (52)
Insects :-						
Anisopteran nymphs	6.1 (9)	-	-	-	-	-
Corixids	11.8 (36)	-	2.3 (30)	0.2 (5)	-	-
Coleoptera larvae	1.5 (5)	-	-	-	-	-
Trichoptera larvae	-	-	-	-	1.3 (17)	-
Hymenoptera	-	3.8 (37)	-	-	-	-
Chironomid larvae	7.4 (23)	-	1.6 (22)	-	-	-
Chironomid pupae	3.0 (9)	-	-	-	-	-
Unidentified insects	-	-	-	-	1.5 (19)	
All insects	29.8 (82)	3.8 (57)	3.9 (52)	0.2 (5)	2.8 (36)	-
Amorphous remains	-	6.3 (62)	2.5 (34)	4.0 (80)	0.8 (11)	0.1 (+)
% fullness	32.5	10.0	7.4	5.0	7.5	13.1
Number of stomachs	7	2	2	2	6	8
Size range (mm T.L.)	34-49	41-44	37-41	42-48	35-50	32-45

TABLE 12.18

Comparing estimates obtained during the present investigations of production and biomass at different trophic levels in the three main sectors of Lake Turkana.

Sectors	North	Central	South
Primary :-			
Primary production rate (mgC/m^2/d)	1315- 6220	194- 3936	259- 293
Secondary :-			
a) Production rate *Tripodiaptomus banforanus* (mg dry wt/m^3/d)	13.5	6.2	1.7
b) Concentration (No/l) of main Zooplankters :-			
Tropodiaptomus banforanus	55.8	30.3	31.4
Mesocyclops leuckarti	14.9	6.3	5.5
Thermocyclops hyalinus	5.1	2.2	1.4
Diaphanosoma excisum	2.9	0.5	0.2
Moina brachatia	0.5	0.2	0.1
Total planktonic crustacea	89.4	46.5	40.9
Tertiary :-			
Biomass pelagic fish (tonnes/km^2)	6.4	3.3	1.0



CHAPTER 13

CONCLUSIONS AND RECOMMENDATIONS

by
A.J. Hopson

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INTRODUCTION

It is clear from the findings of the present survey that in many respects the fisheries biology of Lake Turkana conforms to a pattern common to most major African lakes. The results demonstrate, however, a number of singular features which are correlated both with the unique combination of environmental factors affecting the lake and with its recent geological history.

This final chapter commences with a short review of the major environmental factors influencing the ecology of Lake Turkana. The sections which follow, briefly highlight the most important conclusions drawn from the surveys of phytoplankton, zooplankton and fish. Major fisheries, both actual and potential, are then identified. Estimates of standing stock and production at various trophic levels are compared, and predictions of yield in the future fisheries are made. The work ends with a list of recommendations.

ENVIRONMENTAL FACTORS

Lake Turkana lies in an enclosed basin and as a result of evaporation, conductivity is gradually increasing at the rate of 0.45 S/cm per year. Although the present level of 3500 S/cm is high compared with other major African lakes, the fish fauna (with the exception of mormyrids - see page 292) is apparently unaffected. The presence of populations of Clarias lazera, Synodontis schall, Sarotherodon niloticus and Haplochromis rudolfianus in Crater Lake A on Central Island, which probably became isolated from Lake Turkana about 80 years ago and where the conductivity has now risen to over 11,000 S/cm, suggests that fishes in the main lake will adapt to increasing concentrations and will not be adversely affected by high salinity in the foreseeable future. Present conductivity levels are, however, thought to have had a deleterious effect on marginal vegetation and compared with other major African lakes, Lake Turkana is poor in swamp vegetation. This in turn has resulted in a low detrital content in the sediments with a correspondingly sparse benthic fauna.

The strong prevailing southeasterly winds were found to be an environmental factor of considerable importance in Lake Turkana. Wind-induced surface currents in the top six or seven metres were strong enough to create subsurface counter-currents which resulted in mixing throughout the water column. As a result, a permanent thermocline was never formed, and the deepest portions of the lake were always well oxygenated. Areas of upwelling were observed near the east coast of the lake, but due to thorough mixing of the hypolimnion the upwelling water was not rich in nutrients and these areas were not associated with high productivity. The wind-generated surface currents were, however, responsible for the drift of zooplankton in a northwesterly direction across the lake. This led to an accumulation of zooplankters near the west shore at lake depths of ca 10-30 m, in a longitudinal band extending from south of Kerio to the Northern Sector. Concentrations of the small pelagic fish Alestes minutus and A. ferox, together with their predators, were exceptionally dense in this area as a result of the continually replenished supply of zooplanktonic food. It seems likely that such concentration of prey, as a result of wind action, has enabled stock densities of pelagic fish in Lake Turkana to be maintained well above levels which an evenly distributed zooplankton would support. The distribution of littoral fish was also influenced by the direction of the prevailing winds and high-energy beaches on the west coast supported much smaller populations than the sheltered east coast where sub-littoral beds of *Potamogeton* developed.

Lake temperatures were extremely stable and fluctuated only slightly during the course of a year. The most profound seasonal changes in Lake Turkana resulted from the annual flooding of the River Omo which reached a peak between August and October each year. Several important species of fish, including *Alestes baremose*, *Citharinus citharus*, *Distichodus niloticus* and *Barbus bynni* migrated into the river for the purpose of spawning. Apart from these anadromous forms, the breeding activity of many fish which spawned within the actual lake was greatest during the flood season, probably as a response to the passage of water rich in sediments into the lake. Markedly lowered salinities were noted only in the extreme north of the lake, but during August and September a sediment plume extended southwards to cover most of the Central Sector. Light penetration was reduced in the turbid water and as a result, the pelagic fish of the midwater scattering layer moved nearer the surface and demersal fish migrated close inshore, bringing about a major redistribution of biomass. With increasing distance southwards from the Omo delta, the influence of the turbid flood water diminished and the delay pending its arrival grew. Thus, in the extreme south, a slight increase in turbidity was noted as late as March.

The input of nutrients into the lake during the Omo flood season initiated changes in algal populations particularly in the Northern Sector, marked by increased primary production and the appearance of blooms of *Microcystis aeruginosa*.

Marginal areas of the lake were affected by an annual increase in water level of approximately 130 cm which occurred between late July and October as a result of the Omo floods. On shorelines where flat terrain fringed the lake, as at Ferguson's Gulf and at Kerio, a zone up to 800 m wide was thus inundated annually. In certain years, when the lake shores were lightly grazed by domestic stock, extensive areas of grassland were converted into shallow temporary marshes by the rising water and provided a source of shelter for fishes, particularly young *Sarotherodon niloticus*.

Long term changes in lake level are dependent on precipitation in the catchment area of the River Omo. There has been a net fall of approximately 1.5 m since 1968, but this was preceded by a rapid rise of 4 m between 1961 and 1962. Providing no dramatic climatic changes occur, the lake will probably continue to fluctuate within 2-3 metres of its present level. The reduction in the discharge of the River Omo, which has led to the recent net fall in lake level, is believed to have had an adverse effect on the recruitment of *Citharinus citharus* during the present decade. It seems likely that nursery grounds on the flood plains of the river have shrunk considerably as aa result of the diminished flow.

ALGAE AND PRIMARY PRODUCTIVITY

Phytoplankton populations in the open waters of Lake Turkana were dominated by blue-green algae and were characterised by a low species diversity. The algae were not uniformly distributed and there were marked differences in species composition between the north and the south. Primary productivity and algal biomass both showed a distinct gradient along the axis of the lake, from high values in the north to very low in the extreme south, as illustrated by the following values of gross production rate in gC/m^2/day:

Northern Sector	1315-6220
Central Sector	194-3936
Southern Sector	259- 293

Daily rates of production varied considerably with location and with season. Primary productivity rose to a peak during the post-flood season in the Northern Sector when *Microcystis* was the predominant species.

The open water phytoplankton of Lake Turkana was almost entirely uncropped by either fish or crustacea. Post-larval *Engraulicypris stellae* of up to 9 mm FL, which grazed *Surirella* and similar diatoms, were the only habitual phytoplanktivores in the open lake. *Micralestes acutidens*, under exceptional conditions of food shortage, ingested large quantities of *Microcystis*, but no other open water form was observed to feed on phytoplankton. A very high proportion of the organic carbon produced by the photosynthetic activity of open water algae thus passes through a process of decomposition before it becomes available to the zooplankton in the form of detritus, and an extra step is thus added to the food chain.

Ferguson's Gulf, in common with other similar inshore areas, proved to have an algal flora which was quite distinct from that of the open lake. The phytoplankton was chiefly composed of blue-green algae dominated by *Anabaena circinalis*. The gross rate of primary production was relatively high, averaging 4147 gC/m^2/d and was thus similar to values observed in the Northern Sector of the main lake. However, in Ferguson's Gulf, *Sarotherodon niloticus* grazed the phytoplankton heavily, and as a result of this direct link with the primary producers, fish yields were phenomenally high.

On the sub-littoraal fringes of the lake rich communities of attached algae, often containing a wide diversity of species, occurred on a variety of surfaces including mud, sand, rock and the leaves and stems of macrophytes. Although generally absent from loose substrates on high energy shorelines, epilithic algae grew profusely on rock surfaces subject to strong wave action. In the southern basin where phytoplankton densities were very low, attached littoral algae made a significant contribution to primary productivity and were grazed extensively by *Sarotherodon* and *Tilapia*.

The failure of fish to utilise phytoplankton in the open waters of the lake may be due to the relatively low algal concentrations in deeper water where, although primary productivity on an areal basis is usually comparable with adjacent marginal situations, the algal cells are spread over a much greater vertical range. It seems likely that as a result of the diffusion of algal food resources in the open lake, concentrations fall below a threshold at which it is possible for phytoplanktivorous fish such as Sarotherodon spp. to feed efficiently.

ZOOPLANKTON

In the absence of a well developed benthic fauna, the proportion of fish feeding on zooplankton in Lake Turkana was unusually high. Tropodiaptomus banforanus, a calanoid copepod, was the dominant species of the open lake and accounted for a relatively high proportion of secondary production. Mesocyclops leuckarti, a cyclopod copepod, was also common and ubiquitous but although several cladocerans occurred regularly, their importance was relatively low in terms of biomass. Protozoa were sometimes numerically important but never approached the crustacea in terms of biomass, and Rotifers were generally uncommon.

Production rates for T. banforanus in mg dry wt/m^3/d for the three sectors of the lake were estimated as follows:

North 13.5 - Central 6.2 - South 1.7

These results show that, as with primary productivity, there was a marked decrease from north to south. The trend is probably characteristic of all the major open water planktonic crustacean species. Although there was considerable regional and seasonal variation in zooplankton densities, there was no general tendency for biomass to be lower in the Southern Sector as illustrated by mean concentrations for T. banforanus in No/l:

North 56 - Central 30 - South 31

These values belie the true trophodynamic situation. Pelagic fish densities were much higher in the Central Sector of the lake than in the south and it is clear that the observed level of zooplankton concentration in the Central Sector was the result of heavy predation. In the Southern Sector, pelagic fish were scarce and the relatively high ratio of density to production in T. banforanus may be attributed to low predation rates. The results suggest that zooplankton densities in the south are close to a limiting level below which it becomes inefficient for pelagic fish to feed. Limiting levels were certainly approached in the Central Sector of the lake as a result of predation. Under such circumstances the effects of wind-induced drift, mentioned earlier in this section, were probably of considerable importance in replenishing food supplies for pelagic fish in their centres of concentration near the west coast.

In the extreme north of the lake, populations of zooplankton crashed during the flood season. This may have been due to the adverse effects of lowered salinity or high sediment load. However, exceptionally heavy concentrations of zooplanktivorous fish, particularly Alestes minutus, were noted in the area, and the dearth of zooplankton may have been partly the result of overpredation. In the absence of normal food, many fish were found to have ingested scales.

The present studies prove conclusively that populations of zooplankton over most of the lake are cropped heavily by fishes, and that there is a relatively efficient transfer of energy from the secondary producers to higher trophic levels.

FISHES

Forty eight species of fish have been identified from Lake Turkana. Twelve of these are essentially riverine and were confined to the region of the Omo delta. The fauna is basically soudanian and includes a number of commercially important species which form the basis of large-scale fisheries over extensive areas of Africa, from the Nile valley, through the Chad, Niger and Volta basins to the River Senegal. Ten of the species are, however, endemic to Lake Turkana.

The fauna is well adapted to the environmental conditions and all major trophic niches appear to be occupied, with the exception that no species of fish grazed regularly on the open water phytoplankton dominated by blue-green algae. *Sarotherodon niloticus* which is capable of assimilating *Microcystis* spp., the chief algal genus involved, is restricted to inshore areas of Lake Turkana.

In most respects, the biology of soudanian species occurring in Lake Turkana followed similar patterns to those observed in riverine and lacustrine habitats elsewhere. This applies particularly to breeding activity which, as mentioned above, reached a seasonal peak during the Omo flood season in nearly all species. Fish with strong anadromous tendencies such as *Alestes baremose*, *Citharinus citharus*, *Distichodus niloticus* and *Barbus bynni* underwent characteristic long distance migrations into the river Omo for the purpose of spawning.

Several soudanian species, however, occupied atypical habitats in Lake Turkana. Thus although *Synodontis schall* occurred as a demersal species both inshore and offshore, and fed on benthic organisms such as ostracods and molluscs, the results indicate that it was principally pelagic in distribution. The dominant demersal fish in the deeper areas of the lake was *Bagrus bayad*, a species widespread in shallow riverine situations elsewhere.

Endemic species were particularly important in the pelagic and deep water environments of Lake Turkana. The comparative unsuitability of species of riverine origin for such habitats was probably an important factor which led to their evolution. The vertical zonation of pelagic fish in the open waters during the hours of daylight is one of the most distinctive features of fish distribution in Lake Turkana. *Alestes minutus* and *A. ferox* formed the midwater scattering layer, a discrete band of fish up to 4 m in depth. The depth of the layer below the surface varied from 1-2 metres in extremely turbid water to over 30 metres in the clear water of the southern basin. *Alestes baremose* and *Hydrocynus forskalii* predominated in the surface waters, and *Lates longispinis* and *Schilbe uranoscopus* were the principal species in a zone below the scattering layer. Further offshore, the water column between the communities described above, and the bottom, was populated mainly by well dispersed adult *Engraulicypris stellae* and mature prawns, *Macrobrachium niloticum* and *Caridina nilotica*. With the onset of darkness, extensive vertical migrations occurred with most species tending to migrate towards the surface. Although analgous situations have been described from other major African lakes, the formation of a discrete midwater scattering layer during the hours of daylight appears to be unique to Lake Turkana. In terms of biomass, *A. minutus* proved to be the predominant species of fish in the lake and formed an important link in the pelagic food chain between the zooplankton and predatory fish such as *Synodontis schall*, *Hydrocynus forskalii* and *Lates longispinis*. The acoustic survey indicated a mean stock density of approximately 37 tonnes/km for pelagic fish in the open lake at lake depths greater than 10 m. It is interesting to compare this value with estimates of the standing stock of small crustacea of the zooplankton in Lake Turkana, which ranged with locality from 80 to 200 tonnes/km^3, with a mean of 120 tonnes/km^3.

Fish production and biomass varied considerably from area to area within the lake. There was an obvious tendency for stock density to decrease from north to south, which clearly parallels similar falls in primary and secondary production discussed above.

In the Northern Sector the situation was obscured by the concentration in the area of anadromous fish from all regions of the lake prior to spawning migrations up the River Omo. Thus although the highest values of catch per effort for species such as *Citharinus citharus* and *Alestes baremose* were recorded in the extreme north, the fish production which the catches represented was derived from a much greater lake area. Apart from such considerations, the indications are that high rates of primary and secondary production led to significantly greater areal densities of fish in the Northern Sector than in more southerly areas, particularly inshore demersal forms such as *Labeo horie* and adult *Barbus bynni*.

Pelagic fish, which predominated in the Central Sector, were chiefly concentrated in the western half of the lake between the 10 and 30 m contours. Offshore demersal populations, with *Bagrus bayad* contributing most of the biomass, were more sparsely and evenly distributed throughout the deeper waters. Shorelines tended to shelve more steeply in the Central Sector than in the North and the inshore zones were correspondingly narrower. Shallow bays on the east coast, such as Allia, with dense stands of *Potamogeton* were, however, extremely important centres of fish distribution with large cichlid species particularly abundant closer inshore. High energy shorelines on the west coast of the Central Sector were generally thinly populated with fish, but an inshore zone within the 15 m contour formed a valuable feeding area for demersal species such as *Labeo horie*.

Ferguson's Gulf, situated on the west coast of the Central Sector, must be considered as a separate entity. The efficiency with which algal food is utilized by *Sarotherodon niloticus* in the gulf and the resultant extremely high rates of fish production were unmatched by any other area of comparable size in Lake Turkana. Thus in 1973 the production of *S. niloticus* from an area of 10 km^2 in Ferguson's Gulf amounted to over 16000 tonnes, which was equivalent to more than four times the total catch of fish from the whole of the main lake during that year.

Overall densities of fish were generally low in the Southern Sector of the lake chiefly as a result of a dearth of pelagic species. The abundance of offshore demersal fish, however, increased considerably in the deeper waters of the southern basin to reach a lakewide peak. The increase was probably due to the relatively high biomass of prawns, principally *Macrobrachium niloticum*, in the deeper areas. As noted previously, primary production in the Southern Sector was locally high in communities of attached algae which thrived in the littoral region down to a depth of 2-3 metres. The algae occurred ubiquitously on all shores in the southern basin, including precipitous coasts to the south west of the lake, and were grazed extensively by *Sarotherodon niloticus* and *Tilapia zillii*. These larger cichlids contributed significantly to fish production in the Southern Sector.

COMMERCIAL FISHERIES

On the basis of the present studies six main fisheries, either actual or potential, have been identified in Lake Turkana:

(i) INSHORE GILLNET FISHERY

This fishery, which employs bottom-set gillnets, has yielded a high proportion of the commercial catch from Lake Turkana in recent years. The principal species are Hydrocynus forskalii (approaching maximum size), Citharinus citharus, Distichodus niloticus, Labeo horie, Barbus bynni and Lates niloticus. The area at present exploited lies chiefly on the west coast of the lake between Kerio and Todenyang and extends offshore to the 15 m contour. Although the fluctuation of annual catches between extremes of 2800 and 3800 tonnes during the period 1970-1975 indicated relative stability, species composition of the catch has changed considerably. Thus the proportion of the total yield formed by Citharinus citharus fell from 80% in 1970 to 0.3% in 1975. This decline is attributed partly to exploitation and partly to environmental changes in the River Omo where the spawning grounds are situated. Citharinus citharus appears to be particularly sensitive to the effects of fishing and CADWALLADR and STONEMAN (1966) noted a decline in catches of the same species in Lake Mobutu (formerly Lake Albert) from 287 tonnes in 1954 to zero in 1961 followed by a slight recovery in subsequent years.

In Lake Turkana total catch has been maintained at its current high level partly by expansion into new areas, but chiefly by a reduction in mesh size which has tended to increase the species diversity of the catch. Thus in 1974 Labeo horie and Barbus bynni, caught mainly in 5 and 6 inch nets, together contributed 41% of the total catch. The steady evolution of the inshore gillnet fishery, which would undoubtedly have led to an eventual decline in total yield, was disrupted in early 1975 by the rapid expansion of the Sarotherodon fishery in Ferguson's Gulf. With the attraction of unusually high catches in Ferguson's Gulf, fishermen began to move into the area from communities throughout the entire inshore fishery. By mid-1975 over 75% of all Turkana fishermen had concentrated in Ferguson's Gulf and as a result, fishing effort fell considerably in the inshore gillnet fishery.

Future developments clearly depend on the stability of the Sarotherodon fishery in Ferguson's Gulf since if this fails, fishermen will return to the inshore fisheries of the main lake. It is considered that the effects of the current reduction of effort will be beneficial to the inshore gillnet fishery. As recommended below, legislation should be introduced to limit stretched mesh size to a minimum of six inches. The area of ca 1100 km^2 currently exploited, which includes portions of the east shore from the southern extremity of Allia Bay, could be increased by approximately 200 km^2. Potential inshore fishing grounds exist on the north east coast between the National Park boundary and the Ethiopian frontier, and in the south eastern portion of the lake between El Molo Bay and Nakwe.

(ii) FERGUSON'S GULF Sarotherodon FISHERY

Since early 1975 an exceptionally important gillnet fishery for Sarotherodon niloticus has developed in the Ferguson's Gulf area which, as mentioned above, has attracted a high proportion of the total fishing population of the lake. Thus by August 1976 a total of 121 canoes and 420 rafts were operating an estimated total of 6332 gillnets within the confines of the gulf. Catches have been very high with a total of 1996 tonnes in 1975 increasing to an estimated 16100 tonnes in 1976. Since the fish are concentrated in an area of approximately 10 km^2 this represents a yield of 1610 tonnes/km . Gillnets have been used exclusively. During 1975 a variety of stretched mesh sizes, principally from 3 to 5 inches, were in use but during early 1976 legislation was introduced which limited mesh size to a minimum of five inches.

It is believed that the remarkable rise in *Sarotherodon* production in Ferguson's Gulf was due to a marked decrease in mortality among fry and juvenile fish during 1974 resulting from a chain of climatic and socio-ecological events. The flood plains bordering Ferguson's Gulf are normally heavily grazed by domestic stock but due to good rainfall over the hinterland in 1974, the pastoralists migrated away from the lake. As a result, a thick cover of grass formed on areas surrounding Ferguson's Gulf, and when the lake rose seasonally between August and October, a shallow marsh ca 10 km^2 in extent was formed. Conditions for fry survival and growth within the marsh appear to have been optimal, and by January 1975 high stock densities of adolescent fish formed the basis of the new fishery. Similar conditions during 1975 led to the formation of comparable areas of marsh. If the above hypothesis is correct, it is obvious that a return to heavy stock-grazing in the vicinity of the gulf will lead to a decline in the *Sarotherodon* fishery.

The Ferguson's Gulf *Sarotherodon* fishery must be treated as a distinct entity and management policies should be formulated separately from those of the inshore gillnet fishery. Thus although a minimum stretched mesh size of six inches has been recommended for the inshore fishery, a mesh size of five inches is considered satisfactory for the *Sarotherodon* fishery.

(iii) *SAROTHERODON* BEACH SEINE FISHERY

Both commercial and experimentl fishing on the east shore of Lake Turkana have shown that important resources of *Sarotherodon* spp. and *Tilapia zillii* exist. During 1974 it is estimated that a total fo 304 tonnes of large cichlids were caught in seine nets on the east coast between Jarigole and Sandy Bay. Experimental fishing indicates that the proportion of other species occurring in the catches was low, particularly when larger mesh sizes were used. Further beaches suitable for the seine netting of *Sarotherodon* exist between Porr and El Molo Bay, and in the south east corner of the lake at Nakwe. A minimum mesh size of five inches stretched mesh should be employed.

(iv) OFFSHORE DEMERSAL FISHERY

Long-lining for demersal populations of *Bagrus bayad* was introduced by NORAD master fishermen during 1972 in the Central Sector of the lake off Kataboi. Yields of *Bagrus bayad* together with small numbers of *B. docmac* and *Lates niloticus* were initially high, but after a few months fishing in a particular area, catches fell to uneconomic levels. High catch levels were restored by moving to fresh areas. The long lines were highly selective and only large *B. bayad* of over 50 cm FL were caught regularly. The total yield of B. bayad during 1974 amounted to 262 tonnes. Potential fishing grounds extend throughout the deeper waters of the lake below the 40 m contour, a total area of approximately 2500 km^2. Management policy should be to restrict the number of long-liners to a few highly mobile units. This would enable a small section of the fishing community to obtain a regular livelihood in a fishery which requires above-average investment in the motorised boats necessary to work the offshore grounds.

(v) ALESTES BAREMOSE FISHERY

This fish is not at present exploited but potential yields are considered to be high. The species is readily caught in surface-set gillnets of 2½ to 3½ inches stretched mesh in coastal waters throughout the lake. Maximum catch rates were, however, recorded in the Northern Sector where Alestes baremose concentrates prior to spawning migrations up the River Omo. Apart from A. baremose, the fine mesh surface gillnets also regularly caught a significant proportion of Hydrocynus forskalii, and Synodontis schall at times occurred abundantly.

The establishment of a separate fishery using fine-mesh gillnets would clearly require careful monitoring to ensure that the nets were not used in the other major gillnet fisheries. It is suggested that the Alestes baremose nets should measure a maximum of 2.0 m from headrope to footrope; that stretched mesh size should be limited to between 3 and 3½ inches and that the fishing grounds should be restricted to a lake depth greater than 7.5 m. Experimental data (Table 8.25 a-r) indicate that at such a depth the catch of immature stages of larger commercial fishes would be negligible.

(vi) PELAGIC FISHERY

The present survey indicates that pelagic species form a high proportion of the standing stock of fish in Lake Turkana, and that populations are concentrated off the west coast between the 10 and 30 m contours from Meriar northwards. Alestes minutus, the dominant species in terms of biomass, attains a maximum size of only 3 cm. It is therefore too small to be considered as a possible commercial species unless an industrial fishery is contemplated. A potential fishery however exists for larger predatory members of the pelagic community including Synodontis schall and Lates longispinis, with a minor proportion of Schilbe uranoscopus. Significant quantities of S. schall are already caught in the inshore gillnet fishery, but the probable yield from the pelagic fishery is much greater.

An acceptable fishing technique for pelagic stocks has yet to be worked out. High catch rates were obtained with the bottom trawl in areas of the lake where the midwater scattering layer impinged on the bottom. Midwater gillnets were also moderately sucessful in the vicinity of Longech Spit, but have yet to be tried in a region where stock densities of pelagic fish were currently high. A major drawback to gillnets is that Synodontis schall becomes seriously tangled due to the locking, serrated fin spines and it is difficult to extricate from the gear.

The implementation of a pelagic fishery in Lake Turkana clearly requires further study. The Boris midwater trawl was operated only during the final two months of the present survey. This coincided with the late flood period when pelagic fish were concentrated nearer the surface and closer inshore than at other times of the year. Areas of high pelagic fish density, located by the acoustic surveys close to the west coast of the Central Sector, were probably too near the shore during October-November 1975 to be included in the Boris midwater trawl catches. More exploratory fishing should be undertaken with this net.

It is also suggested that pelagic fishing gear in use on other major African lakes, including encircling nets and light-attraction techniques, should be tried on Lake Turkana.

YIELD PREDICTIONS

GULLAND (1970) provides the following expression for assessing the maximum potential long term yield fo a stock of fish:

$$C_{max} = XMB_o$$

where C_{max} = maximum yield, M = the instantaneous coefficient of natural mortality and B_o = the virgin biomass.

The value of X is given by

$$X = \frac{F_{max}}{M} \cdot \frac{B_{max}}{B_o}$$

where B_{max} is the biomass and F_{max} is the instantaneous coefficient of fishing mortality under conditions giving maximum yield.

Estimations are simplified by a table provided by GULLAND (*op.cit.*) in which values of X are shown for various combinations of c and $\frac{M}{K}$, where c = the length at first capture expressed as a proportion of L_∞, the asymptotic length and K = the von Bertalanffy growth coefficient.

During the present investigations estimates of the various parameters have been made wherever possible, but due to practical difficulties vital information is missing for a number of species. Thus, in the case of *Alestes baremose*, although satisfactory estimates of K, L_∞, and M were made, it has not proved feasible to express gillnet catch per effort in terms of absolute stock density, and hence B_o is not available. Under such circumstances data from fisheries elsewhere in Africa have often provided guide lines for approximations to be made for similar populations in Lake Turkana. Estimates of parameters obtained during the present investigations are summrised in Table 13.1.

SSENTONGO and LARKIN (1973) have used the relationship between mean length (l) and length at first capture l_c to obtain an estimate of Z, the instantaneous coefficient of total mortality by means of the following expression:

$$Z = \left(K. \frac{n}{n+1}\right) . \frac{1}{(y-y_c)}$$

$$\text{where} \quad y = -\log n \left(1 - \frac{\bar{l}}{L_\infty}\right)$$

$$y_c = -\log n \left(1 - \frac{l_c}{L_\infty}\right)$$

and K = the von Bertalanffy growth coefficient.

This method was used to calculate values of Z for *Lates longispinis* and the siluriform fishes caught in the bottom trawl (Table 13.1). Since the populations concerned were virtually unexploited, Z = M.

Although a von Bertalanffy growth curve was not calculated for *A. minutus*, monthly length frequency histograms suggest that the values of K and L shown in Tble 13.1 provide a reasonable approximation to the pattern of growth in this species. In the absence of precise information on mortality, a value of M = 5.2 has been used. COULTER (1977) quotes this figure for *Stolothrissa tanganicae*, the predominant pelagic species in Lake Tanganyika, which like *A. minutus* has an abbreviated life cycle of one year.

No direct estimates of K and L have been made for *Lates niloticus* during the present study. GULLAND (*op. cit.*), however, considers that in cases where growth parameters are unavailable, a value of 0.5 may be used for X in his computation of maximum yield:

$$C_{max} = 0.5\ (MB_o)$$

It seems likely that the natural mortality rate is low in *Lates niloticus* which, from work elsewhere in Africa (HOSPON, 1972), is known to survive to an age of at least 15 yeaars. A value of M = 0.15 has therefore been used to provide an approximation of C_{max} for this species.

Yield predictions (Table 13.2) have been made in cases where all the necessary information for a species is available. These forecasts are subject to the strict provisos which were laid down when the original estimates of stock density were made (see Chapter 8, page 592). A comparison of estimates of biomass with those for yield (Tables 8.3 and 13.2) shows that in a short-lived species such as *A. minutus* with a rapid rate of turnover and a high natural mortality rate, annual yield may be several times greater than standing stock. In long-lived species where the natural mortality rate is low, the converse is true and thus a relatively high standing stock of *Lates niloticus* will sustain only a low annual catch.

The predicted yields (Table 13.2) may also be compared with current catch levels (see Chapter 6, Table 6.19). Commercial catch remained comparatively stable within the various co-operative areas during the period 1972-1974, but the 1974 total of 508 tonnes for *L. niloticus* was already nearly half the estimated long-term yield. Annual catches of the other currently exploited commercial species listed in Table 13.2 are at present well below the estimated yields, particularly in the caase of *Synodontis schall* (Table 6.19).

Major commercial species for which it was not possible to calculate potential long-term yields fall into two groups: (a) heavily exploited species, (b) lightly exploited species. Certain approximations can be made regarding future levels of total catch.

(a) The heavily exploited species, *Citharinus citharus*, *Distichodus niloticus*, *Labeo horie* and *Barbus bynni* are inshore demersal forms, which until recently dominated the commercial fisheries of Lake Turkana. Trends in annual catch (in tonnes) have been as follows:

	1972	1973	1974	1975
Citharinus citharus	666	400	108	10
Distichodus niloticus	480	287	108	84
Labeo horie	586	794	1034	466
Barbus bynni	87	315	442	237

It is estimated that the 1970 catch of *C. citharus* amounted to 3000 tonnes and a dramatic decline in yield is evident. This has been attributed partly to heavy exploitation. There seems little doubt that the standing stock of *C. citharus* has fallen to a level where it can no longer be considered a species of commercial potential. This situation is unlikely to alter unless a change in environmental conditions in the River Omo results in a greatly increased rate of recruitment. Such a pessimistic view of future prospects is supported by data from Lake Mobutu (formerly Lake Albert) where, as mentioned previously, CADWALLADR and STONEMAN (1966) reported a similar failure in the *C. citharus* fishery between 1954 and 1959 with no sign of a substantial recovery during the subsequent six years.

The total catch of *Distichodus niloticus* fell by over 80% in Lake Turkana between 1972 and 1975, and a similar fall in catch per effort (in kg/fisherman/week) was noted between 1972 and 1974 (see Chapter 6, Table 6.30. There is no sign that catches had become stabilised at the 1975 level of 84 tonnes and it seems likely that under the present conditions, the long-term annual yield will lie below this value. CADWALLADR and STONEMAN (1966) (*op. cit.*) showed that in Lake Mobutu the total annual catch of *Distichodus* spp. similarly fell from a peak of over 400 tonnes to fluctuate at levels below 100 tonnes.

With the decline of *C. citharus* and *D. niloticus*, *Labeo horie* and *Barbus bynni* have become the mainstay of the inshore gillnet fishery. The rise in the yield of *L. horie* and *B. bynni* between 1972 and 1974 was due to the use of increasingly smaller mesh sizes. Catch per effort fell throughout the same period indicating that yields were well above C_{max}. Recent legislation which has fixed the minimum stretched mesh size at 5 inches is considered beneficial, but there is a strong case for increasing the minimum legal size to 6 inches in the inshore fishery. The mean retention lengths (FL in cm) recorded for *L. horie* and *B. bynni* in 5 and 6 inch gillnets were as follows:

	5 inch	6 inch
Labeo horie	51.1	57.3
Barbus bynni	41.9	47.0

Catches in the 5 inch nets contained a significant proportion of immature fish, and although it is difficult to predict what result such removal of pre-adults might have on stocks, the affects are likely to be deleterious. An increase in the minimum stretched mesh size to 6 inches would remove the possibility of damage to stocks.

The increase could be achieved without altering the potential sustainable yield, even if no advantage accrued from the protection of immature fish. The reasons are as follows:

The four major species under review are all comparatively long-lived fish in which values of M/K are certainly less than 1.0 and probably close to 0.5. Yield tables produced by BEVERTON and HOLT (1966) show that when the rate of exploitation (E) is high, the sustainable yields of such species reach a peak when the fish are harvested at lengths well above 50% of their maximum size. It is considered that values of E are likely to be very high in the inshore fisheries of Lake Turkana when values of catch per effort fall so rapidly. Estimated L_∞ values of 64 cm and 94 cm have been obtained for *Labeo horie* and *Barbus bynni*, and in 5 inch nets the lengths at first exploitation (l_c) would thus correspond to 80% and 44% of the asymtotic length. The yield Tables from BEVERTON and HOLT (*op. cit.*) indicate that with M/K = 0.5 and E = 0.8 there would be no appreciable change in the long-term yield of *L. horie* if l_c rose to 89% of L_∞ as a result of introducing a 6 inch minimum mesh size. In the case of *B. bynni* a slight increase is predicted.

The inshore fishery for *L. horie* and *B. bynni* is clearly unstable, and although it is predicted that yields will decline rapidly from the peak 1974 values of 1034 and 442 tonnes, it is difficult to forecast at what level catches will reach an equilibrium. Data provided by CADWALLADR and STONEMAN (1966) for Lake Mobutu (formerly Lake Albert) suggest that *L. horie* populations are more stable than those of *B. bynni*.

(b) The lightly exploited commercial fish for which it has proved impracticable to calculate potential long-term yields consist of *Sarotherodon niloticus*, *Hydrocynus forskalii* and *Alestes baremose*.

Catches of *Sarotherodon niloticus* in Ferguson's Gulf rose to the spectacular level of 16,000 tonnes during 1976. The fishery was based almost entirely on young fish which were approaching, or had just reached, sexual maturity at an age of 12 months. High production rates were achieved through the efficiency with which *S. niloticus* cropped the dense algal populations in the gulf, combined with a very high level of recruitment. The evidence suggests recruitment levels are dependent on environmental factors controlling the amount of cover available on the shores of the gulf for fry (see page 1349). Since rainfall, the principal factor concerned, varies considerably from year to year in the Ferguson's Gulf area, it is probable that the annual catch of *S. niloticus* will also fluctuate widely. The 1976 total, equivalent to a production rate of 16,000 kg/ha probably lies close to the maximum potential yield under optimal environmental conditions.

If the hypothesis linking the level of recruitment with the availability of cover proves correct, measures could be taken to stabilise yields of *S. niloticus*. Possible measures include fencing off areas of lake shore to protect marginal vegetation from grazing by domestic stock, the irrigation of such fenced-off areas during the pre-flood period to promote the growth of grass, and the provision of artificial cover in the form of brushwood fences.

The yield per area recorded for *S. niloticus* in Ferguson's Gulf during 1976 greatly exceeds levels of production recorded in other

African lakes and reviewed by LOWE-McCONNELL (1975). It is also high compared with production rates in intensively cultivated fish ponds. The possibility of increasing *S. niloticus* yields by the establishment of fish farms on the shores of Lake Turkana should be considered. There are many shallow depressions close to the margins of the lake which might be converted into culture ponds for *S. niloticus* at relatively low cost. The need for further research in this field is stressed in the recommendations below.

Potential yields of *S. niloticus* from the beach seine fishery on the east coast of Lake Turkana are certainly low compared with Ferguson's Gulf. The annual catch is not likely to exceed several hundred tonnes.

Alestes baremose and *Hydrocynus forskalii* form the basis of the potential surface gillnet fishery using gear of 3 to 3½ inches stretched mesh. A significant portion of large sized *H. forskalii* are already caught in the inshore fishery, particularly in the Todenyang area, and an annual catch of 318 tonnes was recorded during 1974. There is a possibility that these larger fish, which usually exceeded 50 cm FL, belong to a separate, principally riverine stock (see Chapter 9, page 756). Typically, *H. forskalii* matures at ca 30 cm FL in Lake Turkana and with high mortality in post-spawners, only a small percentage of fish exceed 40 cm FL. These smaller *H. forskalii*, together with *A. baremose* of similar size, are at present virtually unexploited by Turkana fishermen. Although no estimates of biomass are available, high levels of catch per effort were recorded, with the following mean values (in kg/100m/night) for a total of 110 nights combining data for the whole lake:

Hydrocynus forskalii	11.7
Alestes baremose	26.8

Catches of *A. baremose* were considerably greater in the Northern Sector. These values compare favourably with other regions of Africa where *Alestes baremose* is a commercially important species. Thus in Lake Mobutu (formerly Lake Albert) HOLDEN (1963) recorded catches per effort for 3 inch surface set gillnets ranging from an equivalent of ca 20 to 40 kg/100m/night for various localities. It may be inferred from the similarity of these values with the present catch per effort data that stock densities of *A. baremose* in Lake Mobutu and Lake Turkana were also similar. CADWALLADR and STONEMAN (1966) showed that *A. baremose* was the predominant commercial species in Lake Mobutu. The fishery for *A. baremose* started to increase in importance from 1956 onwards and the annual yield from Ugandan waters rose steadily to reach 8000-9000 tonnes between 1963 and 1965. This level of production was considered to be well below the maximum sustainable yield. The area of the Ugandan sector of Lake Mobutu is less than half the area of Lake Turkana. It therefore seems likely that the *A. baremose* fishery of Lake Turkana will exceed that of Lake Mobutu in importance, and a potential long-term yield of at least 10,000 tonnes seems feasible.

If a similar analogy with Lake Mobutu is drawn for *H. forskalii* in Lake Turkana, it is probable that after an initial increase, annual catches will fall to well below 1000 tonnes.

The predictions for all species are summarised in Table 13.3.

RECOMMENDATIONS

(1) The following fisheries should be regarded as separate entities, each requiring a distinct policy for management and regulation:

(a) Inshore gillnet fishery using bottom set gillnets of multifilament nylon with a minimum stretched mesh size of 6 inches. The fishing area includes coastlines throughout the lake down to a depth of 10 metres with the exception of Ferguson's Gulf and the National Park.

(b) Ferguson's Gulf *Sarotherodon* fishery using multifilament gillnets with a minimum stretched mesh size of 5 inches. This fishery is restricted to the confines of Ferguson's Gulf.

(c) *Alestes baremose* fishery using surface set gillnets of multifilament nylon with a stretched mesh size ranging from 3 to 3 ½ inches and with a maximum depth from headline to footrope no greater than 2 metres. The fishing area includes open waters throughout the lake at depths greater than 7.5 metres.

(d) *Sarotherodon* beach seine fishery using a minimum mesh size of 5 inches. The fishing area includes all suitable shorelines on the east coast outside the boundaries of the National Park.

(e) Pelagic fishery exploiting stocks of midwater fish at depths greater than 10 metres, particularly species associated with the midwater scattering layer. The most suitable method of capture has yet to be determined.

(f) Offshore demersal fishery using longlines principally for the capture of *Bagrus bayad* in the deeper waters of the lake.

(2) The collection of statistics initiated during the course of the present project should be continued and expanded to cover each of the fisheries outlined above. The records should include:

(a) Total monthly catch for each species in each statistical area.

(b) Data collected at three-monthly intervals in each statistical area relating to catch per effort in experimental gear, length frequencies of fish both in experimental and commercial catches, numbers of fishing craft, fishermen and nets.

(3) The major rivers should be recognised as being of particular importance to a number of major commercial species with anadromous breeding habits. Since such fish are particularly vulnerable during their spawning migrations, fishing in rivers should be restricted to traditional methods already practised, and the deployment of gear should be prohibited within 200 m of active river mouths.

(4) Regular monitoring of the fry of commercial fish should be carried out at Todenyang. Fortnightly samples should be collected from a number of regular sites in this area, using a fine foot seine.

(5) Of the numerous lines for further investigation suggested by the present survey, the following are considered particularly important:

(a) A detailed study of the population dynamics and feeding ecology of the *Sarotherodon niloticus* stock in Ferguson's Gulf in relation to environmental changes. In view of the exceptionally high yields recorded in the fishery, it is felt that this work would be of international interest.

(b) A feasibility study to investigate the possibilities of establishing aquaculture based on *Sarotherodon niloticus* on a large scale on the shores of Lake Turkana.

(c) Further studies on the pelagic fisheries of Lake Turkana with the object of establishing practical fishing methods.

(d) The failure of fish to utilise the openwater phytoplankton directly should be investigated in greater detail. The possibility of introducing a phytoplanktivorous species which would efficiently fill the vacant niche in the offshore waters of the lake should be examined.

(6) Methods of processing fish should be re-examined by an expert in the field. The results of this survey indicate that species such as *Citharinus*, *Distichodus* and *Labeo*, which have hitherto formed the mainstay of the commercial fishery will be replaced largely by *Alestes baremose*, *Synodontis schall* and *Sarotherodon niloticus* in the future. The present method of salting and sundrying practised by co-operative fishermen is unlikely to be the most suitable technique in the years to come.

It will be appreciated that the potential importance of each species is a product of the estimated yield of the unit value. Wide variations in commercial value are possible in species such as *Labeo horie* which is currently marketed in a low-value salted-sundried form. *Labeo horie* is regarded as a luxury food in the Kisumu area and if a cheap method of transporting fresh fish could be devised, the unit value of the commercial catch of this species might be up to ten times higher than at present. To achieve the full potential value of the fisheries, processing and marketing should be examined separately for each species.

REFERENCES

BEVERTON, R J H and HOLT, S J (1964). Tables of yield functions for fishery assessment. FAO Fish. tech. Pap. (38) : 49 pp.

CADWALLADR, D A and STONEMAN, J (1966). A review of the fisheries of the Uganda waters of Lake Albert. Suppl. Publ. No 3, E. Afr. freshw. Fish. Res. Org. Jinja, Uganda. 19 pp.

COULTER, G W (1977). Approaches to estimating fish biomass and potential yield in Lake Tanganyika. J. Fish. Biol. 11 : 393-408.

GULLAND, J A (1970). The fish resources of the oceans. FAO Fish. tech. Pap. (97) : 425 pp.

HOLDEN, M J (1963). Report on the fisheries of Lake Albert. Fisheries Laboratory, Lowestoft (mimeographed).

HOPSON, A J (1972). A study of the nile perch (Lates niloticus (L) Pisces: Centropomidae) in Lake Chad. Overseas Res. Publ. 19 : 93 pp, London, HMSO.

LOWE-McCONNELL (1975). Fish communities in tropical freshwaters. London and New York, Longman. 337 pp.

SSENTONGO, G M and LARKIN, P A (1973). Some simple methods of estimating mortality rates of exploited fish populations. J. Fish. Res. Board Can. 30 : 695-698.

TABLE 13.1

A summary of parameters estimated for various species of fish during the present investigations and used in the prediction of yield.

Species	K (/yr)	L_∞ (cm)	M (or Z)	B_o (tonnes)
Hydrocynus forskalii	-	-	-	-
Alestes baremose ♂♂	0.40	48	1.94	-
Alestes baremose ♀♀	0.33	55	1.02	-
Alestes ferox	-	-	-	18,700
Alestes minutus	1.2	4.2	5.2	187,000
Citharinus citharus	0.22	66	0.51	-
Distichodus niloticus	-	-	-	-
Labeo horie	0.24	74	-	-
Barbus bynni	0.2	92	-	-
Schilbe uranoscopus	1.03	36	1.88	1,300
Bagrus bayad	0.26	84	0.80	8,300
Synodontis schall	0.73	32	1.37	25,000
Lates longispinis	0.31	70	1.11	7,450
Lates niloticus	-	-	-	14,800
Sarotherodon niloticus	-	-	-	-

TABLE 13.2

Predictions of annual yield in tonnes based on estimates of growth and mortality parameters and of virgin biomass.

Species	Proposed length at first capture (cm)	Percentage of B_o in exploited stock	Maximum sustainable yield (tonnes per year)
Alestes minutus	2	90	560,000*
Schilbe uranoscopus	20	50	600
Bagrus bayad	45	50	1,650
Synodontis schall	20	95	22,000
Lates longispinis	28	55	1,800
Lates niloticus	60	95	1,050

* This may be regarded as an approximate value for *Alestes minutus* plus *Alestes ferox.*

TABLE 13.3

Forecasts of probable sustainable yields for all major species of fish in Lake Turkana.

Species	Estimated yield (tonnes)	Notes
Hydrocynus forskalii	up to 1,000	No reliable estimates of stock density for Lake Turkana. Values based on catch data for Lake Mobutu (formerly Lake Albert) provided by CADWALLADR and STONEMAN (1966)
Alestes baremose	10,000+	
Alestes minutus	560,000	Pelagic fish of very small size. Of commercial importance only if fish meal production contemplated. No satisfactory method of harvesting yet devised.
Alestes ferox		
Citharinus citharus	0-50	Reliable estimates of stock densities not available. Predictions based on recent trends in commercial catches combined with data from CADWALLADR and STONEMAN (op.cit.)
Distichodus niloticus	0-100	
Labeo horie	200-500	
Barbus bynni	100-200	
Schilbe uranoscopus	600	see Table 13.2
Bagrus bayad	1,650	
Synodontis schall	22,000	
Lates longispinis	1,800	
Lates niloticus	1,050	
Sarotherodon niloticus	500-22,000	The higher value realisable if optimal conditions for fry survival prevail in Ferguson's Gulf. Lower value represents probable yield for remainder of lake.
Others	200	

MAIN APPENDICES

1 An annotated checklist of invertebrates recorded in Lake Turkana

2 Specifications of the welded steel research vessel *Halcyon*

MAIN APPENDIX 1

AN ANNOTATED CHECKLIST OF INVERTEBRATES RECORDED IN LAKE TURKANA

A J D Ferguson

The following checklist is based on material collected during the present survey both during routine investigations into the biology of the openwater plankton (Chapter 3) and in the course of the shore survey (Chapter 7). Additional samples of benthic material were collected with the aid of an Eckman grab and an anchor dredge.

In certain groups, notably the crustacea, most of the collections have been satisfactorily identified to species level. Much of the material, particularly the insects, awaits examination by specialists. (NB * = new record for Lake Turkana).

PROTOZOA

LOBOSA

Difflugia cf limnetica Levander*

Very few rhizopod protozoa were found in Lake Turkana but Difflugia cf limnetica occurred in a few shore samples taken with a fine mesh net in sheltered areas near the Kerio and Turkwell river mouths. None was recorded from the open water or in samples from the east side of the lake.

HELIOZOA

Raphidiophrys cf pallida F E Fch*

The distribution of this common planktonic species in open water is discussed in Chapter 3. The species was generally scarce near the shore but occurred regularly in samples from exposed sites on the west coast.

CILIATA

Loricata

Vaginicola sp. nov.*

The distribution and abundance of this common open water species is also described fully in Chapter 3. Few were taken in samples from less than 10 m of water but, as with other planktonic protozoa, they were occasionally found in shore samples on exposed coastlines, particularly on the west side of the lake.

Vaginicola subcylindrata Hadzi*

This form was normally found attached to diatoms in open water but also occurred sparingly on larger sessile diatoms in shore samples throughout the lake. The species was not associated with any particular shore type but was found to be commoner on firm substrates with relatively rich diatom populations.

Vaginicola cf *ampulla* Stokes*

A small and rather rare species occurring epizoically on Ostracod shells. It was found on several Ostracod species but was never in samples from the east coast. Examples were also recorded on Ostracods taken in benthos samples at sites near the west coast in water up to 10 m deep.

Lagenophrys wallengreni Abonyi*

This species was also found on Ostracod shells but was generally more common than *V.* cf *ampulla*. Specific host preferences were not determined during the present survey but results from shore samples indicate that various forms of Ostracod provided suitable attachment sites. In contrast to the previous species, individuals of *L. wallengreni* were found in shore samples taken on the east coast and from benthic material from water deeper than 10 m.

PERITRICHA

(i) *Sessilia*

Peritrich ciliates were generally abundant in shore samples and although specific identification was not possible during the present survey, several forms were readily distinguishable. In open water they were epizoic on zooplankton and epiphytic on *Microcystis* colonies.

Epistylis spp.*

In shore samples, two forms of this genus were easily distinguished by differences in their stalk structure. Both were common, particularly in sheltered areas, all round the lake and no marked ecological differences in their distribution were found. It appears, however, from the result of net collections at shore survey sites, that one of the forms was more common at sites where *Potamogeton* stands were dense.

In open water a species of *Epistylis* ws found on the later stages of cyclopoid copepods. Occasionally the infestations were extremely heavy, particularly on *Mesocyclops leuckarti* from plankton samples near the shore.

Vorticella spp.

At least three morphologically distinct forms of this genus were found in samples during the present survey. Two occurred in shore smples, and the third was observed in open water plankton samples. The open water form was found associated with *Vaginicola* sp. nov. and on *Microcystis* colonies. The morphology of the individuals on *Vaginicola* and on *Microcystis* was very similar, but a more thorough examination may prove that they are two separate species.

(ii) *Mobilia*

Trichodina steni Clapul*

This ectoparasite of fish was found only on shore samples from the east side of the lake and was associated with samples from sites where *Potamogeton* was abundant. The hosts of this species were not established during the present survey but, as the protozoan was not found in the open lake, it seems likely that they were inshore species such as *Barilius niloticus*.

Sperotrichium elegans Wulff*

Few examples of this species were found in net samples since maximum size was smaller than the aperture size of net usually employed. Relatively large numbers were found in samples collected for estimating densities of small algae, but as few bottle samples were collected at the shore survey sites, the distribution and relative abundance of *S. elegans* near the shore remains unsolved.

SUCTORIA*

At least two species of this group were found in the shore survey samples and one species was found to occur epizoically on copepods in open water. The latter species was particularly abundant on copepod nauplii.

Both inshore species were widely distributed and were distinguished by their size. One was unusually large with a body diameter of over 50 m and a stalk width of 16 m. This species was associated with plant debris at sheltered sites throughout the lake. The second and smaller species was found in samples from more exposed sites but since the material was usually detached, substrate preferences were not established.

PORIFERA

Spongilla cf *lacustris* Imhoff*

The identify of sponges remains uncertain since fruiting bodies were not found. However, spicule formation suggests that all material is referable to the same species, probably *S. lactustris*. Most examples were recorded on rocky coasts and the sponge was particularly common in the South Sector where substrates were generally firmer. Material was also found on an outcrop of rock at a depth of 20 m, due east of Longech Spit. Sponges were not encountered on soft muddy substrates which predominated in offshore areas of the lake.

TURBELLARIA

Gyratrix hermaphroditus Ehrenberg*

A common species in openwater plankton samples throughout the lake, and also found in net samples taken during the shore survey. As with other open water planktonic species, this rhabdocoel was more abundant in samples from exposed sites, particularly on the west coast.

ROTIFERA

Brachionus plicatilis (Muller)

The distribution and abundance of this species in the open water is discussed in detail in Chapter 3. The results showed that in the open waters, *B. plicatilis* declined in abundance from north to south. Relatively large numbers were found in shore samples throughout the lake where sheltered conditions prevailed.

Brachionus calciflorus (v. *dorcas*) (Pallas)

Common in the plankton of the North Sector and near the mouth of the Omo River, but very rarely encountered in the open water of the Central or Southern Sectors. A similar distribution was noted in the shore survey samples although the species was relatively common in sheltered sites near the mouth of the Kerio River. None was found on the east coast south of Koobi Fora.

Brachionus quadridentatus Herman*

Restricted to shore samples from very sheltered sites (e.g. the inner region of Allia Bay in association with dense stands of *Potamogeton*). The species was rarely encountered on the east coast south of Allia Bay and increased in abundance towards the north.

Brachionus caudatus/angularis group

Common in the north of the lake and in sheltered lagoons near the Kerio and Turkwell river mouths but rarely encountered elsewhere. Required less sheltered situations than the previous species.

Brachionus dimidiatus Bryce

Rarely recorded from open water away from the northern extremity of the lake but at times abundant in marginal lagoons. In common with other rotifer species this form occurred in the actual lake near the mouth of the Omo River.

Brachionus falcatus Zacharias*

Never recorded from the actual lake or from marginal lagoons but observed in the River Omo and from fresh water pools in the gorges of the Kalokol and Kataboi Rivers, where the conductivity of the water was less than 700 S/cm.

Keratella tropica Apstein*

A rare species observed only in the Northern Sector in both open water and shore samples.

Felinia terminalis (Plate)*

Common in the open water but decreasing in abundance towards the south end of the lake. Recorded from shore survey samples only on the east coast as far south as Koobi Fora (cf *Branchionus calciflorus*) and on the west coast in relatively exposed situations.

Felinia opalensis (Zacharias)*

Restricted to open water sites in the extreme north of the lake near the Omo delta.

Hexarthra jenkinae Beauchamp*

The distribution and abundance of this common open water species has been described in detail in Chapter 3. This was the dominant open water rotifer of the Central, Turkwell and Southern Sectors but only rare individuals were noted in shore samples, except in exposed situations on the west coast.

OLIGOCHAETA

Very few oligochaetes were found in benthic or shore samples. A small collection was examined by Trevor Reynoldson but much of the material was unsuitable for specific identification. Individuals resembling *Tubifex tubifex* were found in benthic samples from the vicinity of Longech Spit in 3 m of water, and from a depth of 20 m on the north side of Koobi Fora Spit. Lumbriculid worms were also found in samples of benthos from Ferguson's Gulf at a depth of 2 m.

HIRUDINEA

Placobdella fimbriata (Johansson)

Common on the teeth of crocodiles all round the lake. First found by the Cambridge Expedition (1930-31) and identified by MOORE (1933).

Other leeches of uncertain identity (probably *Glossiphonia nilotica* Johansson) were found at a few sites on the shore survey where substrates were predominantly stony.

CRUSTACEA

CALANOID COPEPODS

Tropodiaptomus banforanus Kiefer

By far the most abundant zooplankton species (see Chapter 3 but relatively rare in shore samples, particularly in water less than 0.5 m deep and in stands of marginal vegetation.

CYCLOPOD COPEPODS

Mesocyclops leuckarti Claus

The second most abundant zooplankter in openwater situations (see Chapter 3). Almost all the net samples taken during the shore survey included this species which was usually the dominant form, particularly in exposed to partly sheltered situations. The reason for the increased importance of this species in marginal areas is not clear but the phenomenon is probably related to the ability of *M. leuckarti* to utilise a wide variety of food organisms.

Thermocyclops hyalinus Rehberg

Widespread in both openwater and shore samples where usually the second most important cyclopoid copepod, but not usually a common species.

Thermocyclops emini (Mrazek)*

Absent from the open water plankton and restricted to sheltered inshore situations and to enclosed lagoons. A rather rare species but widely distributed round the lake.

Ectocyclops hirsutus (Kiefer)*

Absent from the open water plankton but commonly encountered in shore survey samples from sheltered situations throughout the lake. More abundant on the east shore particularly in the south, becoming rare in the north.

Afrocyclops gibsoni (Brady)*

Absent from the open water plankton and similar in distribution to Ectocylops hirsutus. Rarely found in exposed localities subject to heavy wave action. Typical habitats were Allia Bay, Ferguson's Gulf and sheltered sites near the Kerio and Turkwell river mouths. Also found in association with stands of Potamogeton, particularly in the north.

Microcyclops varicans Fryer*

Only found at a few sites on the east coast in sheltered areas associated with beds of Potamogeton.

Eucyclops eucanthus Sars*

A few examples of this rather rare species were found at shore survey sites near the south end of the lake and in one open water plankton sample in this region.

PARISITIC COPEPODS

A small collection of parasitic copepods was made during the present survey. The material has been examined by Dr G Fryer and the species found are listed below. The numbers collected were too small to warrant any comment on their distribution or abundance.

Argulus brachypeltis Fryer

Males and females of this species were found free swimming in metre townet samples and on Alestes baremose.

Argulus cunningtoni Fryer

This species was also found unattached in metre_townet samples from the open water and occurred on Alestes baremose and Lates niloticus.

Argulus rhipidiophorus Monod

In contrast to the other argulids, A. rhipidiophorus was not found in metre townet samples, but several males and females were collected from Lates niloticus

Argulus sp. nov.

A single female argulid which probably belongs to a new species was obtained in a metre townet sample from the open water of the lake.

Opistholernaea longa (Harding)

Examples of this species were first found by members of the Cambridge Expedition (1930-31). During the present survey this species was observed regularly on Lates niloticus in offshore waters of the lake, and L. longispinis was at times heavily infested.

Lernaea barnimiana (Hartmann)*

Observed on Labeo horie and Barbus turkanae.

Lernaea sp.

A juvenile lernaeid was found on Alestes nurse from the Kerio River mouth.

CLADOCERA

Sididae

Diaphanosoma excisum Sars

Most open water plankton samples and many shore survey samples included this species and, as with the other open water zooplankters, they were common at sites exposed to the prevailing southeasterly winds on the west side of the lake. Noticeably rare in sheltered situations on the east coast.

Daphnidae

Hyalodaphnia barbata Weltner

Recorded from both open water samples and during the shore survey but was less common than the other Cladocera. High densities were occasionally recorded, suggesting that the distribution was patchy.

Ceriodaphnia rigaudi Richard

Widely distributed in the open lake (see Chapter 3) but rarely found in shore survey samples.

Moina brachiata (Jurine)

A widely distributed species both in the open lake and at shore survey sites, but less common in sheltered areas.

*Moina micrura**

This species was more common than *M. brachiata* in sheltered areas near the north end of the lake and near the mouths of the Kerio and Turkwell Rivers. Populations were also found in permanent freshwater pools in the gorges of the Kalokol and Kataboi Rivers.

Macrothericidae

Macrothrix laticornis (Jurine)

Many examples of this species were collected in shore survey samples from sheltered locations throughout the lake. The species was not found in sufficient numbers for any conclusions to be drawn regarding substrate preferences.

Chydoridae

Alona affinis (Leydig)*
Alona rustica T Scott*
Alona guttata Sars*
Alonella diaphana King*

Alona rustica was the most abundant of these species which were all found occasionally at sheltered sites on both sides of the lake, particularly where submerged marginal vegetation or stands of *Potamogeton* were abundant. *Alona rustica* was also found in a few samples from more exposed sites on the east coast in the north.

Leydigia cf *propinqua* Sars*

A rare species recorded only from two sites on the north east side of the lake and from Ferguson's Gulf.

OSTRACODA

A relatively large number of ostracods and wide species diversity have been found in Lake Turkana, particularly in the littoral zone. Many of the species listed below were originally recorded by LOWNDS (1936) or LINDROTH (1953), and most were found in littoral or benthic samples during the present survey. The most common shore species have been marked with a cross.

CYPRIDAE

Ilyocypris gibba Rhamdohr

CYPRINAE

Onocypris worthingtoni Lowndes

Cyprinotus auratus (Klie)

Cyprinotus fossulatus Vaora

+ *Cyprinotus kliei* (Lindroth)

Sclerocypris venusta (Vaora)

Sclerocypris clavularis Sars

+ *Sclerocypris* cf *jenkinae*

Sclerocypris sp.

Strandesia minuta Klie

Cypridopsis caaerulescens Klie

Cypridopsis newtoni (Brady and Robertson)

+ *Potamocypris producta* Sars

Potamocypris worthingtoni Lowndes

+ *Megalocypris brevis* Sars

DARWINULIDAE

+ *Darwinula stevensoni* (Brady and Robertson)

CYTHRIDAE

+ *Limnocythere africana* Klie
L. africana s. sp. *minor* Lindroth
Cyprideis torosa (Jones)

CARIDEA

Macrobrachium niloticum Roux

Common, at times abundant in the openwaters of the lake. Adults penetrate into marginal waters only in the Northern Sector during flood period. Zoeal and juvenile stages are confined to offshore areas.

Caridina nilotica Roux*

Similar in distribution to *M. niloticum* and at times equally abundant. Adults were, however, restricted to offshore areas at all times.

INSECTA

The most abundant insect grops found on the shore survey were the Chironomidae and Hemiptera Heteroptera, but examples of many other groups of aquatic insects were also found. The majority of the less common forms were found either in shallow organogenic sheltered sites with stands of marginal vegetation and *Potamogeton*, or on relatively sheltered stony shores. Neither of these habitats was common on the margins of Lake Turkana.

EPHEMEROPTERA

Representatives of this family were frequently encountered in samples taken on the shore survey, from a variety of habitats.

BAETIDAE

At least two species of this group were recorded in the shore survey samples. In most cases they occurred on stony or rocky shores subject to a relatively high degree of wave action. Baetids were noted most commonly on stony shores on the east side of the southern basin and on South and Central Islands.

CAENIDAE

One species resembling the genus Caenis was found frequently in shore survey samples from sheltered muddy sites, mainly on the east side of the lake, but also near the Kerio River mouth. It is evident from the results that they were locally abundant near the north end of the lake and in Allia Bay.

POVILLIDAE

Povilla sp.

This species was locally abundant and featured in the diet of several littoral benthic fish including Synodontis schall. Very large numbers were found burrowing in a reef of soft sandstone at a depth of 20 m due east of Longech. Relatively large numbers were also found in Allia Bay and near the mouth of the Kerio River.

PLECOPTERA

One plecopteran nymph, probably a representative of Perlidae, was found on the rocky shores of the south basin.

HEMIPTERA

Anisops sardea
Anisops worthingtoni Jaczewski
Anisops Hutch
Micronecta ras Hutch

Large numbers of aquatic hemipterans were found at many sites around the lake, including relatively exposed situations lacking marginal vegetation where protection from heavy wave action was provided by sandspits or lagoons. Aquatic hemipterans were also found in sheltered organogenic sites with stands of marginal vegetation. Their general abundance is indicated by the frequency with which they were recorded in the food of littoral fishes (see Chapter 12).

COLEOPTERA

A total of seven species of Coleoptera larvae or adults were recorded from Lake Turkana by IMMS (1933) and BALFOUR-BROWN (1939). Coleopterans found during the present survey were not identified to species level.

TRICHOPTERA

Larvae of the families Hydropsychidae, Limnophilidae, Polycentropidae and Leptoceridae were found during the shore survey, but none was recorded from benthic samples. Hydropsychid larvae occurred in large numbers on the stony shores of the south basin, but examples of the other groups were comparatively rare and mainly associated with stands of marginal vegetation or with beds of *Potamogeton*.

DIPTERA

CHIRONOMIDAE

BEADLE (1974) has indicated that mass emergences of Chironomidae is a common feature of many African lakes. Lake Turkana is no exception. Large numbers of chironomids were observed around the lake, and larvae and pupae were common food items of littoral fishes, particularly at night (see Chapter 12). The more common species appeared to emerge on a lunar cycle. A lack of on-site information precluded specific identification of the larvae collected during the shore survey and from benthos samples, but observations on the mouth-parts of the larvae indicated that there were at least five common species, and many more less common. The habitats used by the larvae were extremely varied, but the number of species was greatest in sheltered situations and fell with increasing exposure to wave action. Densities of larvae also declined with increasing exposure but the unstable sandy shores apparently supported less chironomid larvae than equally exposed stony shores.

A series of Eckman Grab samples from twelve sites on a transect from inside Ferguson's Gulf to Station H1 in 80 m of water just north of Central Island, showed that the number of benthic chironomids decreased from at least five species at a depth of 2 m, to three species in 10 m of water off the end of Longech Spit, and to only one species below the 30 m contour. The results also indicated that the abundance of the chironomids decreased dramatically with depth. This general trend was confirmed by anchor dredge samples taken all over the lake during the course of the project.

OTHER DIPTERA

Larvae of other dipteran groups were generally scarce. Ceratopogonid and Ephydrid larvae were found at sheltered and partially exposed sites associated with muddy substrates. One very noticeable absentee from the samples was the larva of *Chaoborus* species which has been found abundantly in many other Africn lakes. It is interesting to note that several *Chaoborus* larvae were found during the present survey in relatively fresh water pools in the Kataboi gorge only 5 km from the edge of the lake, but Chaoborids were never found in the main lake.

GASTROPODA

Only four species of gastropod were found in Lake Turkana during the present survey. The reasons for the very low species diversity remain obscure but are probably associated with the relatively high salinity of the water, and low habitat diversity. It is evident from a short survey of recent fossil gastropods carried out at a site 10 km south west of Ferguson's Gulf by J LANDYE of Arizona State University in December 1974, that the lake supported a much more varied gastropod fauna in relatively recent times. The list of species identified by J LANDYE and D S BROWN from this site includes Biomphalaria pfeiferi, Bellamya unicolor, Pila speciosa, Gyraulus costulatus, Segmentorbis angustus and Bulinus (B) sp. in addition to all the present day species listed below.

Melanoides tuberculata (Mull)*

A relatively common species in anchor dredge and Eckman grab samples from muddy substrates but not found in marginal areas. The benthic samples indicate that the abundance decreases from north to south and with increasing depth. None was collected in the southern basin despite the presence of apparently suitable substrates.

Cleopatra pirothi Jick*

This species was also frequently collected in benthic samples and was more widely distributed and more common than Melanoides tuberculata in samples taken below 30 m. The maximum recorded depth of this species was 60 m. Unlike the other benthic species, a few C. cf pirothi were collected in shore samples from exposed coastlines.

Gabbiella rosea Mandahl-Barth*

A littoral and sub-littoral species rarely found in benthic samples. A small number were collected by Eckman grab at depths of less than 5 m off Longech Spit. The species was found to be widespread in the shore samples but was mainly associated with fine grained substrates.

Ceratophallus natalensis (Kraus)*

Restricted to shore samples and mainly associated with stony substrates. Unlike other gastropods, C. natalensis increased in abundance towards the south end of the lake and was observed in large numbers on the rocky shores of El Molo Island. The species was also recorded from exposed coastlines with sandy substrates, including the east side of Longech Spit.

REFERENCES FOR APPENDIX 1

BALFOUR-BROWNE, J (1939). Scientific results of the Cambridge Expedition to the East African lakes 1930-1. Coleoptera of the families Dytiscidae and Gyrinidae. J. Linn. Soc. Zool. 40 : 475-485.

BEADLE, L C (1974). The inland waters of tropical Africa. London, Longmans. 365 pp.

IMMS, A D (1933). Scientific results of the Cambridge Expedition to the East African lakes 1930-1. No 10. On some aquatic coleopterous larvae. J. Linn. Soc. Zool. 38 : 301-307.

LINDROTH, I (1953). Ostracods in the inland waters of East Africa. Zool. Bidr. Uppsala 30 : 45-156.

LOWNDES, A G (1936). Scientific results of the Cambridge Expedition to the East African lakes 1930-1. No 16. The smaller Crustacea. J. Linn. Soc. Zool. 40 : 1-31.

MOORE, J P (1933). Scientific results of the Cambridge Expedition to the East African lakes. No 9. Leeches. J. Linn. Soc. Zool. 38 : 297-299.

MAIN APPENDIX 2

SPECIFICATION OF THE WELDED STEEL RESEARCH VESSEL 'HALCYON'

BUILDERS: Campbeltown Shipyard Ltd., Trench Point, Campbeltown, Argyll, Scotland.

Length overall: 49 ft 3 ins

Breadth, moulded: 16 ft

Depth, moulded: 8 ft 3 ins

Draft: 6 ft

Main engine: Kelvin T6 developing 180 SHP @ 1000 rpm with a 2 :1 reduction gear box

Propeller: Single, fixed pitch operating in fixed Kort nozzle

Generators: Two Lister HRW3 with 110V Brush alternators rated at 13.5 KVA

DC supply: 24V off all diesel units

Winch: Rapp CV460/45 fitted with 1 ins circ. warps. The winch was also equipped with a subsidiary drum with 4 mm hydrographic wire

Power block: Rapp 19R

Line-hauler: Rapp LS-120

Echo Sounder: Kelvin Hughes MS44F, 48 Hz

Radar: Kelvin Hughes Type 17

Radio transceiver: Plessey

Endurance: 14 days

Cruising speed: 8 knots

Accommodation for six person

The vessel was rigged as a stern trawler

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